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Review of the Superfund Hazard Ranking System Review by the Hazard Ranking System Review Subcommittee of the Science Advisory Board

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Washington, DC 20460

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January 1988

Review of the Superfund Hazard Ranking System

Review by the Hazard Ranking System Review Subcommittee of the Science Advisory Board

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The Subcommittee suggested changes that will allow the HRS to provide a more accurate and scientifically based estimate of the relative risk of candidate uncontrolled waste sites. Ideally the HRS scores should accurately assess the relative degree of risk at a site, however, we recognize that is not always feasible due to scientific and data limitation and to value and policy decisions implicit when considering and balancing human health and environmental impacts. A revised HRS, better designed to evaluate sites by relative risks, will provide an improved mechanism for determining which sites should be included on the National Priorities List (NPL), and can potentially provide useful input to the subsequent prioritization of NPL sites. Most of the changes needed to improve the current HRS are changes in the risk variables assessed and in the overall algorithm, not changes with vast new data requirements.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

SAB-EC-88-008

January 14, 1988

OFFICE OF
THE ADMINISTRATOR

Honorable Lee M. Thomas
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Thomas:

The Hazard Ranking System Review Subcommittee of the Science Advisory Board has completed its review of a number of issues related to the Superfund Hazard Ranking System (HRS). The Hazard Ranking System is the principal mechanism used by EPA to determine whether an uncontrolled waste site should be placed on the National Priorities List.

Besides evaluating the questions referred by the Office of Emergency and Remedial Response (OERR), the Subcommittee has also chosen to address: the overall algorithm for the HRS, the inclusion of exposure in the HRS, how the HRS could be evaluated in the future, and work which could be done to provide better documentation for the next revision of the HRS.

The Subcommittee has suggested changes that will allow the HRS to provide a more accurate and scientifically based estimate of the relative risk of candidate uncontrolled waste sites. Ideally, the HRS scores should accurately assess the relative degree of risk at a site. However, we recognize this is not always feasible due to scientific and data limitations and to value and policy decisions implicit when considering and balancing human health and environmental impacts. A revised HRS, better designed to evaluate sites by relative risk, will provide an improved mechanism for determining which sites should be included on the National Priorities List (NPL), and can potentially provide useful input to the subsequent prioritization of NPL sites. However, the Agency must continue to base this prioritization on many factors in addition to the HRS. Most of the changes needed to improve the current HRS are changes in the risk variables assessed and in the overall algorithm, not changes with vast new data requirements.

The Office of Emergency and Remedial Response referred three issues to the Subcommittee: the types of toxicity the HRS should address and how it should do so; distances from an uncontrolled hazardous waste site that are relevant when considering air pollutants from the site; the feasibility of including waste concentration in the HRS and whether large volume waste sites had been treated differently than other sites by the HRS.

The Subcommittee finds that all the options OERR proposed for revising the toxicity factor are improvements over the current approach. The Subcommittee believes, given the difficulty of ambient air monitoring, that the inclusion of potential release via the air pathway is an important improvement to the HRS. The Subcommittee also believes that improved characterization of the source and of exposure/mobility will improve the functioning of the HRS for all sites, not just large volume waste sites.

With respect to the three issues posed to the SAB, the Subcommittee recommends the following:

1. In order to improve the discriminating power of the HRS, the currently used Sax rating scale should be replaced by multiple measures of toxicity. In addition, exposure measures need to be improved.

2. Modification of the HRS to include the potential for air release seems both appropriate and possible. A scoring system that weights population exposure in concentric rings is recommended.

3. EPA's experience in applying the HRS to mining sites has not proven biased against such sites, that is, it has not treated such sites with systematic error; however, it has that potential. Our recommendation for improvement includes incorporating hazardous-constituent concentration in a tiered system, modifying the toxicity factor to reflect metal speciation, incorporating a mobility factor, and adding additional transformation factors.

The Subcommittee also recommends that more attempts be made to learn from subsequent experience so that when the HRS is next revised, a better basis for those revisions will be available. These recommendations are detailed in Appendix 6.

The Subcommittee's evaluation of these and other issues, and its conclusions and recommendations, are discussed in greater detail in the attached report. Because of their cross cutting nature, certain issues, such as exposure and the overall algorithm, appear in more than one area.

The Subcommittee would like to call to your attention the high quality efforts of the staff from the Office of Emergency and Remedial Response that briefed and worked with the Subcommittee. They were professional, well-prepared, and responsive to the Subcommittee's requests for information.

We appreciate this opportunity to present our scientific views and look forward to an official written response from the Agency concerning the comments and recommendations in the attached report.

Sincerely,

Norton Nelson, Chairman
Executive Committee
Science Advisory Board

Raymond C. Loehr

Raymond Loehr, Chairman
Hazard Ranking System Review Subcommittee
Science Advisory Board

cc: W. Porter
H. Longest
T. Yosie

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SAB-EC-88-008

SCIENCE ADVISORY BOARD
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE

REVIEW
# of the
SUPERFUND HAZARD RANKING SYSTEM

January 1988

NOTICE

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HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE

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VICE CHAIRMAN

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MEMBERS AND CONSULTANTS

Dr. Stephen L. Brown, Project Manager, Environ Corporation, 1000 Potomac Street, N.W., Washington, DC 20007

Dr. Thomas Burke, Deputy Commissioner, New Jersey Department of Health, Room 805, State Health, CN360, Trenton, New Jersey 08625

Dr. Shepherd Burton, Systems Applications, 101 Lucas Valley Road, San Rafael, California 94903

Mr. George F. Carpenter, Michigan Department of Natural Resources, Environmental Response Division, Post Office Box 30028, Lansing, Michigan 48909

Mr. Richard Conway, Corporate Development Fellow, Union Carbide Corporation, Post Office Box 8361 (770/342), South Charleston, West Virginia 25303

Dr. Paul Deisler, 11215 Wilding Lane, Houston, Texas 77025

Dr. John Doull, Professor of Pharmacology and Toxicology, University of Kansas Medical Center, Kansas City, Kansas 66103

Dr. Naihua Duan, Statistician, Rand Corporation, 1700 Main Street, Santa Monica, California 90406

Dr. Keith Ferguson, Environmental Protection, Environment Canada,
Kapilano 100, Park Royal, West Vancouver, British Columbia
CANADA V7T1A2

Dr. C. Daniel Kealy, U. S. Bureau of Mines, Spokane Research Center,
East 315 Montgomery Avenue, Spokane, Washington 99207

Dr. James O. Leckie, Department of Civil Engineering,
Stanford University, Stanford, California 94305-4020

Dr. Donald Mackay, Department of Chemical Engineering and Applied Chemistry
and Institute for Environmental Studies, University of Toronto,
Toronto, Canada M5S 1A4

Mr. Bruce Napier, Battelle NW, Post Office Box 999,
Richland, Washington 99352

Dr. David Pollock, U.S. Geological Survey, National Center, Mail Stop 411,
Reston, Virginia 22092

Dr. Joseph V. Rodricks, Environ Corporation, 1000 Potomac Street, N.W.,
Washington, DC 20007

Dr. Ellen Silbergeld, Chief Toxics Scientist, Toxic Chemicals Program,
Environmental Defense Fund, 1616 P Street, N.W., Room 150,
Washington, D.C. 20036

Dr. Mitchell Small, Department of Civil Engineering, Carnegie Mellon
University, Schenley Park, Pittsburgh, Pennsylvania 15213

Dr. Rebecca T. Zagraniski, Division of Birth Defects and Developmental
Disabilities, Center for Environmental Health and Injury Control,
Centers for Disease Control, Koger Center Room 2008 (F-37)
1600 Clifton Road, N.E., Atlanta, Georgia 30333

Executive Secretary

Mrs. Kathleen W. Conway, Deputy Director, Science Advisory Board (A-101F),
U.S. Environmental Protection Agency, 401 M Street, S.W.,
Washington, D.C. 20460

Staff Secretary

Mrs. Dorothy M. Clark, Secretary, Science Advisory Board (A-101F),
U.S. Environmental Protection Agency, 401 M Street, S.W.
Washington, D.C. 20460

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EXECUTIVE SUMMARY

The Hazard Ranking System (HRS) is the principal mechanism used by EPA to determine whether an uncontrolled waste site should be placed on the National Priorities List (NPL). The Office of Emergency and Remedial Response (OERR) requested that the Science Advisory Board (SAB) review certain aspects of the technical basis for revising the HRS. The major issues identified by OERR dealt with the toxicity factor, air target distance, and large volume wastes. (See Appendix 7 for the full text of this request).

Overall, the Subcommittee is generally supportive of the changes OERR presented and found no fatal flaws in the approach to the HRS that OERR presented; however, the Subcommittee has made recommendations in this report that would further improve the HRS.

Toxicity Factor

Toxicity should be an important component of a site ranking scheme. Because the toxicity factor in the current HRS makes virtually no distinctions among sites listed or proposed to be on the NPL, and because EPA did not present evidence that it had examined the ability of the various factors to discriminate between sites --including sites not on the NPL--the Subcommittee questions whether the existing toxicity factor has the power to discriminate "very toxic" from "not so toxic" sites. The Sax chemical toxicity ratings are a crude basis for setting priorities since they address only the acute toxicity of one constituent of the waste. The Subcommittee recommends replacing Sax ratings and using multiple measures of toxicity for ranking sites. All of the options presented by OERR are substantial improvements. These options are described in OERR's *Discussion of Options for Revising the Hazard Ranking System (HRS) Toxicity Factor* (12).

Scientific techniques exist which would permit the HRS to consider several endpoints that are revelant to human health and the environment. Multiple measures of toxicity should be considered, any one of which, if sufficiently severe, could, by placing the site on the NPL, trigger a more detailed evaluation. By multiple measures, the Subcommittee means acute human health effects, human cancer, non-cancer chronic disease in humans, and impact on the non-human natural environment. However, a system of weighting the severity of different health endpoints, as is done in the Reportable Quantities (RQ) approach, is not encouraged because a single composite score obscures the value judgments implicit in such an approach.

It is possible that sites containing hazardous chemicals whose toxicities are not well or widely known might be omitted from the NPL, thus creating false negatives. Measures to counter this problem include the continued development of toxicity profiles on additional chemicals and the keeping of good records so that sites can later be re-evaluated when additional toxicity data become available.

Air Target Distance

The Subcommittee supports efforts to modify the air pathway so that it considers the potential for release instead of relying only on a score for observed releases. Air emissions are often episodic and/or narrowly focused along a particular wind direction and, therefore, are difficult to detect. Furthermore, time and site activities (such as excavation in the course of site remediation) can markedly change the potential for air emissions.

Methods are currently available which can be simplified to calculate approximate, order-of-magnitude emission rates for impoundments and landfills. Using them requires information on the chemical identities at the site. When such information is totally lacking, it is impossible to even estimate the quantity of the chemical present, and volatile air emissions can not be predicted. The subsequent consideration of air exposure routes is very weak. A minimum data requirement which mandates contaminant identification by record review or direct sampling (either within containment structure or of emissions) would greatly improve the HRS' validity in all pathways. In the absence of an inventory, direct sampling methods such as soil gas analysis or contained surface sampling complement estimated emissions and provide a more effective estimate than the estimated emissions alone. Such methods normally will yield samples of much higher concentration than ambient air samples, and chemical analyses will be more informative.

The Subcommittee recommends that the Agency derive a scoring system which weights the number of exposed people in a "ring" according to the distance from the site at which they live. (This approach is described in greater detail in Appendix 2 and illustrated by the figure on page A2-12.) The widths of the rings can be determined to account for the decrease in air concentrations with distance.

This ring-weighting method does not account for risks to the maximally exposed individual (MEI), but it does explicitly account for the higher exposures that will occur closest to the site. The Subcommittee does not consider a separate or additional evaluation of MEI air risks as part of the HRS to be necessary. The recommended ring-weighting method will essentially serve the same purpose by weighting most heavily the nearest and most exposed population.

The ring-weighting method should be calibrated on the basis of the variation of concentration with distance. The influence of pollutants borne on particles will likely be concentrated at lesser distances which would change the ring weights, but would not often lead to markedly different scores.

Large Volume Waste

The issues before the Subcommittee were the "applicability of the HRS in scoring mining waste sites" and the "feasibility of using waste concentration data in a revised HRS."

The Subcommittee finds that the studies conducted thus far regarding the adequacy of the HRS listing process for mining sites have been limited and inconclusive. Sufficient evidence based on experience has not been evaluated and presented to show an inadequacy of the HRS in regard to mining sites. However, the present scoring system has a potential to treat mining wastes with systematic error.

The Subcommittee believes the present HRS is not well suited for scoring potential releases from mining site wastes because mobility is not included. Improved ways of considering the concentration (often low), toxicity release (mobility in various matrices), and information on the transport and transformation of chemicals would make the HRS more accurate.

Mobility is a more discriminating concept for both inorganic and organic substances than is persistence in the subsurface, especially with respect to inorganic compounds. The Subcommittee recommends that, during the development of a structured-value representation of the mobility concept, a means of incorporating important matrix characteristics be explored. Significant matrix characteristics are extreme acidity or alkalinity (as expressed by both high and low pH), crystalline phase modifications of mining wastes that differ from native geologic materials, and the sorptive capacity of surrounding geologic materials (influencing migration tendency).

In regard to the surface water route, EPA is considering keeping persistence as the parameter to include with toxicity in the waste characteristics portion of the HRS, but would consider other transformation parameters along with the current use of biodegradation. Inclusion of these additional parameters would improve the existing HRS because it would more closely correspond with what happens in the real world.

It appears from the presentations that OERR would also include mobility in the air route score. Mobility and waste quantity are important factors in determining exposure. Because of this importance, the basic approach of including mobility in the HRS should be pursued. (See also Appendix 2.)

Modifying the current HRS to incorporate factors which capture some measure of both the physical-chemical characteristics of the hazardous constituents and the waste matrix, as well as those site characteristics responsible for risk, is clearly an improvement.

EPA presented two approaches for incorporating concentration into the HRS. While the direct measurement approach provides the soundest scientific basis for the HRS, in most cases, it will not be practical--because of safety and cost considerations--to require waste constituent concentration data for every site at the site inspection stage. In contrast, the tiered approach used hazardous constituent concentration data where available and default values where they were not. The Subcommittee supports the use of the tiered approach because it encourages the gathering and use of concentration data and provides for the use of indirect estimates where data gathering is impractical.

Both approaches translate waste constituent concentration data into an estimate of the total mass of a hazardous constituent at the site, which is then used to compute the waste quantity score for the HRS. The approach that uses the "total mass" of hazardous constituent, without relevant information on metal speciation and mobility, would produce false positives for some large volume wastes and pathways.

For the ground water pathway, the total concentration or mass of a constituent is of much less importance than the leachate concentration produced at the site. Consequently, more emphasis should be placed on the partitioning of hazardous constituents between the solid waste and the leachate. Actual or estimated leachate concentration should then be factored into the waste quantity term in the HRS. For wastes that are in liquid form, total contaminant mass quantity should continue to be used.

Exposure

The Subcommittee believes that toxicity issues are integrally linked to dose, i.e., migration and exposure (see Appendix 4).

Consideration of exposure in the evaluation of relative risk is vital. If there is no exposure, there is no risk and where there is exposure, risk varies with exposure. While the current HRS gives some consideration to exposure, often through the use of proxies such as persistence, distance to nearest well and target populations, the Subcommittee concludes that additional chemical-specific consideration of routes of exposure, particularly with respect to the Toxicity Factor, would strengthen the HRS.

The Subcommittee is mindful of the difficulties in characterizing exposures to chemicals at waste sites that have undergone only preliminary investigation. It does not propose the implemention of expensive and time-consuming sampling programs to measure actual concentrations in ambient media where pollutant levels may be near or below detection limits. However, additional surrogates for exposure--e.g., a calculation of quantity estimates with mobility considerations--will provide better rankings than does the current system. Without appropriate estimates

of mobility, consideration of toxicity in the algorithm is tantamount to assuming that the exposures to every detected chemical at every waste site are equal. The Subcommittee recommends adoption of a tiered approach for exposure similar to Option W3 EPA developed for concentration (discussed in Appendix 3 of this report).

Algorithm

Revisions to the HRS should begin with the development of a chain of logic, without regard for the ease or difficulty of collecting data, that would lead to a risk assessment for each site. This framework, but not the underlying logic, would be simplified to account for the very real difficulties of data collection.

This chain of logic, which is termed the algorithm in this report, should lead to a situation in which an increased score reflects an increased risk presented by a site. Without this consistency in the meaning of a score it is impossible to assess the relative degree of risk posed by a site.

The Subcommittee places special emphasis on the algorithm issue because it is impossible to review the components of the HRS without considering how the components fit together. If the HRS is to evaluate sites by relative risk, then the HRS must be consistent with the underlying, quantitative relationships of the factors involved. Specific recommendations concerning this issue are presented in Appendix 5.

Consistency in terms of relative risk and score does not exist between sites in the current HRS, although for a single site a larger score represents a larger risk. Changes in the HRS algorithm mean that a score of 28.5 in a revised HRS will almost certainly mean something different than a score of 28.5 in the current HRS.

Recommendations To Evaluate and Improve the HRS

Grappling with a difficult problem like the HRS clarifies the need for additional data, studies, and evaluations. The Subcommittee assumes that the HRS will again be revised. Results from the following would be most helpful at that time. Peer review of the plans for such studies is recommended.

- The evaluation of the relative risk of sites as estimated by a HRS score should be compared with the results of risk assessments based on the Remedial Investigation/ Feasibility Studies (RI/FS).

Advance planning is needed so that additional RI/FS-like data is gathered on some sites with scores below 28.5; these can be selected using an a priori sampling scheme. Similarly, since the success of the HRS at ranking by relative risk depends, in part, on the consistency and completeness of the scoring, at least some sites scoring above 28.5 may require additional data gathering. Such work would provide the basis for a meaningful retrospective study of the HRS and a better understanding of the basic parameters that are important in the use of the HRS scoring model.

- EPA should determine, based on results of RI/FS studies, whether the health risk associated with a site was likely to be dominated by one or a few chemicals (for each pathway) or by a larger number of chemicals. Such a review would provide an objective basis for recommending how many chemicals should be selected for toxicity (or site) ranking. The two Agency studies of this issue presented to the Subcommittee were limited in the number and types of sites evaluated, and the sites studied were not selected for representativeness, but for convenience. A better evaluation is warranted.

- EPA should consider, how the scores through the various pathways relate to relative risk. With this information, the algorithm can be calibrated appropriately.

- A vigorous effort should be made to improve the overall quality of analytical data collected at sites. Standardized collection and laboratory methods currently exist for only a small fraction of substances potentially present. Expanded chemical characterization of all media, coupled with a strong laboratory certification program will improve not only the HRS but all aspects of the Superfund process.

- Screening models like the HRS must be simple. They do not have much resolving power and therefore, some false positives and false negatives are inevitable. Because of this limitation, HRS scores should not be overemphasized. A process should be established either to review sites subject to scoring or to review HRS scores in an attempt to spot false positives and negatives. Such a scientific review process could involve the use of additional models; in many cases, however, obvious false negatives or positives might be best handled by a "manual" review. The important point is that the system be flexible enough to allow for a variety of approaches to be used, as needed, during the scientific review process.

INTRODUCTION

The Current Hazard Ranking System: Purpose and Prior Reviews

The Hazard Ranking System (HRS) is the principal mechanism used by EPA to determine whether to place sites on the National Priorities List (NPL). The HRS was made available for public comment on two occassions. On March 12, 1982 a draft of the current version was placed in the Superfund Docket and a notice was published in the Federal Register. EPA summarized the public comments and addressed them in the preamble to the final HRS rule on July 16, 1982. On April 9, 1987 EPA published an Advance Notice of Proposed Rulemaking in the Federal Register requesting comments and information related to revising the current HRS. The Agency subsequently held a two-day public meeting to solicit public testimony. The issues referred to the Science Advisory Board (toxicity factor, air target distance, and concentration) are ones that the public had previously identified.

Required Revisions to the Hazard Ranking System

Section 105(c)(1) of the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that the Agency modify the Hazard Ranking System so that, "to the maximum extent feasible, it accurately assesses the relative degree of risk to human health and the environment posed by sites and facilities subject to review." The amendments require an:

- Assessment of the human health risks associated with contamination or potential contamination of surface waters, either directly or as the result of run-off from a site.

- Evaluation of the damage to natural resources which may effect the human food chain and which is associated with any release or threatened release.

- Assessment of the contamination or potential contamination of the ambient air which is associated with a release or threatened release.

Section 125 of SARA also requires that for certain wastes generated primarily from combustion of coal, EPA consider the following:

"(1) The quantity, toxicity, and concentrations of hazardous constituents which are present in such waste and a comparison with other wastes;
(2) The extent of, and potential for, release of such hazardous constituents into the environment; and
(3) The degree of risk to human health and the environment posed by such constituents."

Section 1187 requires that EPA give a high priority to facilities where the release of hazardous substances has resulted in the closing of drinking water wells or has contaminated a principal drinking water supply.

Science Advisory Board Review

Three memoranda from the Office of Emergency and Remedial Response constitute the request for the review. (Appendix 7 contains copies of these memoranda.) In response to the first memorandum requesting an independent outside scientific review of the technical basis supporting revisions of the HRS the Executive Committee of the Science Advisory Board formed the Hazard Ranking System Review Subcommittee. (The Subcommittee roster appears at the beginning of this report.) The members were chosen for their special expertise and experience in the hazardous waste area.

The Subcommittee first met May 19-20, 1987 in Washington, DC for background briefings on the Superfund program and on the current HRS. OERR provided the Subcommittee and Work Group with briefings on the toxicity factor and air target distance issues, issue papers, and key references. At the July 16-17, 1987 Subcommittee meeting in Washington the Office of Policy Planning and Evaluation (OPPE) orally presented its Site Ranking Panel Study, four ranking systems and expert panel to rank 20 hazardous waste sites.

The Subcommittee formed three work groups to address issues referred by the OERR. These were the Toxicity Factor Work Group, the Air Target Distance Work Group and the Large Volume Waste Work Group. (Rosters for these Work Groups can be found in the front of Appendices 1, 2, and 3, respectively). Each work group reviewed documents on that issue prepared by OERR and reported to the full Subcommittee. (Review and important background documents are listed in Appendix 8.)

The Toxicity Factor Work Group met June 29-30, 1987 in Washington, DC to review Discussion of Options for Revising the Hazard Ranking System (HRS) Toxicity Factor (12). The Work Group reported its conclusions and recommendations to the full Subcommittee July 16-17, 1987.

The Air Target Distance Work Group met July 27-28, 1987 in Washington to review Analysis of the Air Target Distance Limit in the Hazard Ranking System (9).

The Large Volume Waste Group met August 20-21, 1987 in Denver to review two documents, The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites, and The Superfund Hazard Ranking System (HRS): Feasibility of Using Concentration Data in a Revised HRS (13, 14). OERR briefed the Large Volume Waste Work Group. Two members of the public were invited to give presentations to the Work Group. Dr. Ishwar Murarka of the Electric Power Research Institute presented EPRI's utility waste research program (1, 2, 3, 4, 5, 6, 7). Mr. William Bluke of CH2M Hill spoke on his experiences at Superfund mining waste sites. Two members of the public, Dr. Brian Murphy of Gradient Corporation and Ms. Susan Sawtelle representing the Edison Electric Institute and other utility organizations, provided oral comment.

The latter two work groups reported their conclusions and recommendations at the final full Subcommittee meeting held on September 14-15, 1987 in Washington, DC.

Materials given to the Subcommittee were made available to the public through the Superfund Docket. All meetings were announced in the Federal Register and opportunity for both written and oral public comment was provided at each meeting.

The Subcommittee's report was approved by the Executive Committee of the Science Advisory Board on January 14, 1988 prior to transmittal to the Administrator.

Structure and Practice of the Current HRS

The current HRS uses a technique called structured value analysis (or scoring) to rank sites. In the HRS structured value analysis, a set of rules is developed which parallel what is thought to be occurring in the real world. The rules address what factors should be considered, and how they should be scored and combined. The combination rules for the current HRS have been adjusted on the basis of professional judgment--that is, weights have been introduced to make the HRS output match a subjectively ranked test set of sites.

The current HRS, described in Uncontrolled Hazardous Waste Site Ranking System: A Users Manual (8), assigns three scores to a site. Two are used primarily to identify facilities requiring emergency attention. These are the score for Fire and Explosion and for Direct Contact. The third, or Migration score, is the primary basis for inclusion on the NPL.

Three pathways (air, surface water, and ground water) are considered in developing the Migration score. For each pathway, various factors are considered. These fall into three broad categories: likelihood of release, waste characteristics, and targets. The actual factors considered can vary with the pathway. For example, distance to the nearest well applies to the ground water pathway but not to the air pathway.

After a numerical value is assigned to each factor, it is multiplied by a weight to obtain a factor score. Factor scores within the same category are added. Scores for the categories are multiplied together. This procedure yields a score for the pathway. The pathways are then combined through a method called quadratic averaging. Each step in this process affects the final score and, therefore, how well the HRS discriminates between sites of greater and lesser risk to human health and the environment.

EPA and the states use the HRS to calculate a site score, from 0 to 100, based on the actual or potential release of hazardous substances from a site through air, surface water or ground water that may affect people. This score is the primary technical factor used to decide if a hazardous waste site should be placed on the National Priorities List.

EPA, the states and other public agencies have used the HRS to evaluate several thousand sites. The scores and supporting documentation of these sites are submitted to EPA Headquarters where they are reviewed to ensure correct and consistent application of the system. Sites having scores above 28.5 are proposed in the Federal Register for the National Priorities List. Based on public comment and all available information EPA develops a final score for each site and places it on the NPL if the score is still above 28.5.

SUMMARY OF THE ISSUES

Toxicity Factor

The Subcommittee believes that toxicity to human health and the environment is an important consideration in site ranking. To be useful, the toxicity factor should discrimate between "very toxic" and "not so toxic" sites. If the objective of the HRS is to generate estimates of relative risk, it must address both toxicity and exposure. Although toxicity is part of the current HRS, the toxicity factor makes distinctions among only a few of the 951 sites listed or proposed for the NPL.

The Sax chemical toxicity ratings have provided the current HRS with a crude basis for prioritizing sites. The Sax system is insufficient because (a) it focuses on acute adverse outcomes instead of the range of toxicologic endpoints that need to be addressed in the HRS, and (b) it does not provide citations so that toxicologic ratings can be reevaluated and verified for the purposes of the HRS. All of the options (E1, E2, E3) discussed in Discussion of Options for Revising the Hazard Ranking System (HRS) Toxicity Factor (12) represent improvements over the Sax rating method.

The Subcommittee recommends the Sax rating method be replaced with a toxicity factor which addresses multiple measures of toxicity because most known toxic chemicals are associated with a range of health and environmental effects. Therefore, to protect human health and the environment, the HRS needs to incorporate the potential for a wide range of adverse effects. A high score for any of these endpoints could motivate a more detailed evaluation of a site at the RI/FS stage.

To the extent that scientifically legitimate techniques exist for the consideration of various toxic effects in humans and in nature, the decision of which endpoints to address is more of a policy rather than a scientific choice. Nevertheless, because there are so many endpoints relevant to human health and the environment for which good methods exist, the Subcommittee encourages EPA to address multiple endpoints as part of the toxicity factor. The multiple measures of human toxicity EPA should consider addressing with the revised toxicity factor include carcinogenicity, other chronic health endpoints used to establish reference doses, and acute toxicity.

The three options presented in EPA's Discussion of Options for Revising the Hazard Ranking System (HRS) Toxicity Factor (12) make use of essentially the same data bases for toxicity, and none of the options is overwhelmingly superior to the others. However, because there is no scientifically credible basis for weighting the severity of different health endpoints, as is currently done for calculating Reportable Quantities (RQs), the Subcommittee discourages use of the RQ method. Such weightings are subjective;

subsequently, the subjectivity may be obscured by the final numerical score. The strengths and weaknesses of the options are summarized here (see Appendix 1 for more detail).

For acute toxicity, the Subcommittee prefers use of the Registry of Toxic Effects of Chemical Substances (RTECS) method rather than the Reportable Quantity (RQ) method, because RTECS facilitates route-specific toxicity ratings and closer attention to the raw toxicity data.

For non-cancer chronic effects, the Subcommittee prefers use of the Reference Dose (RfD) method because the RQ method involves weighting the severity of various endpoints, and the modified ADI method has not received extensive review and may differ from the RfD method in rating individual chemicals.

For carcinogenic potency the Subcommittee sees little difference between the two options presented (q_1* vs. ED10) and suggests that other measures, e.g., ED(1)and ED(0.1), be investigated.

EPA addressed the question, "How Many Chemicals Should Be Evaluated?" Based on information presented to the Subcommittee orally and in writing (10) it appears that the studies of this topic, while generally indicating only a few chemicals would dominate the health risk associated with a site, were limited in the number and type of sites evaluated and the sites were selected for convenience rather than representativeness. Because of this, and the fact that toxicological information is missing or scanty for many chemicals, the Subcommittee cannot recommend a fixed number of chemicals for OERR to examine at each site. A study to address this question is one of the Subcommittee's recommendations (see page 6).

The Subcommittee recommends that EPA consider the risk represented by the numbers of chemicals known to be present. All things being equal, and because the toxicological effects of so many chemicals are unknown, a site with more chemicals should receive a higher priority in the Preliminary Assessment/Site Investigation (PA/SI) stages for further evaluation. Another approach is the assignment of discretionary points (see Appendix 5).

The Subcommittee could not formulate an absolute recommendation on the question of whether separate toxicity ratings for a chemical should be developed for various exposure routes. Such a route-specific approach has appeal because toxicity is known to vary by exposure route for some chemicals. However, this toxicity question cannot be addressed independently--it is inextricably tied to how the HRS deals with migration and exposure issues. If the revised HRS aggregates route-specific exposure scores, this total exposure score could be multiplied by a net toxicity score which would not need to be route-specific. (The cruder the scheme, the less need for route-specific factors.)

Alternatively, a more accurate analysis would independently evaluate risks by route before aggregating. Route-specific toxicity factors would improve the accuracy of such an approach. Although such toxicity factors are not yet available for a large number of compounds, differences in toxicity between routes is potentially important. EPA may find consideration of route-specific toxicity on an exception basis to be a practical solution especially applicable to compounds such as asbestos where a particular route, in this case inhalation, is well known to be of great importance. Whether or not route-specific toxicity is addressed in the HRS, it is of potential utility in the subsequent RI/FS stage because the more detailed information supports more realistic analyses of risks.

The Subcommittee has discussed the need for two additional steps in the NPL process. First, some type of consistent methodology or guidelines is needed to select chemicals during the preliminary assessment and site investigation for use in the site ranking process. Second, the option of using more detailed risk information, if available, could be used as a supplement to the HRS process (see Appendix 5).

Air Target Distance

The basis for this section of the review was Analysis of the Air Target Distance Limit in the Hazard Ranking System (9).

The Subcommittee is very supportive of OERR's efforts to modify the air pathway so that it considers the potential for releases, instead of relying solely on a score for observed releases.

The air pathway in the current Hazard Ranking System evaluates population risks to derive a score for "air targets" using a matrix of population versus distance for four concentric circles with radii of 1/4, 1/2, 1, and 4 miles.

The Subcommittee recommends that EPA consider alternatives to the use of a single air target distance limit for all sites and derive a scoring system which uses site-specific population rings. The widths of these rings may vary by size and type of site to account for the decrease in air concentration with distance. (See Appendix 2, especially the illustrations in Attachment B.) The Subcommittee favors such a refinement because the ring-weighting method relates more directly to risk at a site than does the current air target approach. The ring weighting method should be able to address risk more accurately because it considers both the population exposure experienced near the site and the toxicity factor.

In the ring-weighting approach, information on the chemicals present is used to estimate emissions factors. These emissions factors and information about the health effects that can be expected to occur at various levels of exposure can be used to develop ring-widths that relate to the exposure people living in those locations can expect to experience.

Although this method does not evaluate maximally exposed individual (MEI) risks per se, it does explicitly account for the higher exposures that will occur within the ring closest to the site. These higher exposures would receive an appropriately weighted score.

The Subcommittee was asked to address approaches to assessing health risks from airborne contaminants and has suggested a variety of approaches for EPA's consideration. All of these approaches employ the following assumptions: carcinogens are non-threshold contaminants; there are thresholds for other toxic effects; concentrations of contaminants decrease with distance from the site; this decrease is more marked for particulates than for volatile chemicals; and acute toxicity and toxic effects from direct contact with particulates are the over-riding health concerns in the area closest to an uncontrolled waste site.

Acute effects are addressed by Superfund's emergency program and by the current HRS toxicity factor which is based on the Sax ratings (see Appendix 1). The Subcommittee favors a toxicity factor which includes multiple endpoints of toxicity including acute effects because some nearby populations around uncontrolled waste sites report symptoms consistent with acute toxicity (headaches, nausea, irritation, and respiratory effects) and because of the possibility of acute effects occuring in the event of a catastrophic release. Because of the weight given the inner-ring such acute effects could be well addressed with the ring-weighting approach or by a ring-weighting approach modified to account for the existence of a threshold concentration below which no acute effects should occur. However, other scientifically supportable options include: considering acute toxicity in a separate assessment outside the HRS (such as under the emergency program); assigning discretionary points to the HRS score for the confirmed presence of local odors or health effects reasonably associated with materials found at the site; a separate assessment of the probability of a release of materials from a catastrophic event; and treatment of acute effects in a direct-contact pathway.

Chronic non-cancer effects could also be addressed with the ring-weighting approach or by one modified to account for the existence of a threshold concentration below which no chronic effects should occur. In the modified ring-weighting approach this threshold concentration can be converted to a distance from the site beyond which no adverse chronic effects would be expected. Chronic effects, particularly of particulate pollutants, could also be treated in a direct contact pathway.

Carcinogens are dealt with in a reasonably precise manner by the ring-weighting approach, given the usual assumption that risk is directly related to average lifetime concentration in air. While the Subcommittee favors this approach, it is complex and EPA may want to evaluate the effects of different diameters to see if the use of a single diameter for all sites is reasonable.

The ring-weighting approach described in Appendix 2 is best suited to carcinogenic effects of volatile chemicals. While concentration of particulates decreases more sharply with distance than does the concentration of volatile chemicals, the Subcommittee believes that this difference is not large enough to require separate estimation methods for volatile and particulate emissions in the HRS.

In assessing exposure, consideration of each media pathway is recommended, including air, water, food and direct contact. Measurement of exposure should also consider the route of exposure through which substances exert their effects. While the relationship between exposure level and the biologically effective dose is different for different pathways, not all compounds are toxicologically well characterized. As a result, EPA may only be able to deal with route-specific toxicity on an exception basis; e.g., in the case of asbestos, inhalation is more important than ingestion.

Many of the Subcommittee's recommendations hinge on knowing the identities of the chemicals at the site. A minimum data requirement which mandates contaminant identification by record review or direct sampling would greatly improve the validity of the HRS in all pathways and is particularly helpful in estimating exposures to air pollutants and in addressing toxicity. For example, when the chemical identities are known, it should be possible to modify and simplify the Treatment Storage and Disposal Facilities (TSDF) procedures to calculate an approximate, order-of-magnitude emission rate for impoundments and landfills.

Both the identity of chemicals at the site and emission rates can be confirmed using other investigative techniques, the most obvious of which is air concentration measurement. Because ambient monitoring is subject to the problem of dilution, to detect the presence and amount of emissions it is desirable to analyze at the source, or as close to the source as possible. There is, thus, an incentive to use methods of "probing" sources using such techniques as soil gas analysis.

Large Volume Waste

The large volume waste issues before the Subcommittee were the applicability of the HRS in scoring mining waste sites and the feasibility of using waste concentration data in a revised HRS.

OERR provided The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites (13) and The Superfund Hazard Ranking System (HRS): Feasibility of Using Concentration Data in a Revised HRS (14) as the basis for the review.

There are two ways to evaluate the applicability of the HRS to mining sites. The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites (13) presents EPA's experience in ranking mining sites with the HRS system in terms of false positives and false negatives and then distinguishes between the sites according to potential danger (determined by other means). In its evaluation, the Subcommittee coupled this approach with an examination of the scientific issues independent of the HRS experience.

In addressing large volume waste (LVW) issues, it is useful to note that clear qualitative differences exist between many LVW and the more numerous hazardous waste sites containing mixed synthetic organic/inorganic hazardous constituents in both liquid and solid form. LVW monofills are materials of a single type. Specific sites may have multiple types of wastes (e.g., mill tailings, smelting slags, etc.). Sites where these wastes are spatially separate are more easily characterized than sites where they are mixed. LVW are commonly contain low concentrations of hazardous trace elements (HTE) in the waste matrix which are released by very specific geochemical processes and subject to migration constraints that are increasingly better understood.

With respect to the question of the applicability of the current HRS to mining waste sites, the Subcommittee finds that the studies conducted regarding the adequacy of the HRS listing process for mining sites have been limited and inconclusive. The reports reviewed included the TRC (27, 28, 29) and MITRE (24, 25) reports contained in The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites (13) as well as EPA's own studies. Sufficient experiential evidence has not been presented to show an inadequacy of the HRS in regard to mining sites. The present system has possibly rated mining sites no worse than other waste sites. Some of the findings supporting this conclusion follow.

(1) While the TRC (27, 28, 29) and MITRE reports (24, 25) reported that mining waste sites scored higher in waste quantity compared to non-mining sites (as expected given the large volume of wastes generated by the mining industry), TRC did not conclude that this bias caused false positives or false negatives for mining sites. Both sets of reports found that waste quantity contributed relatively little to the final HRS score.

(2) Although the TRC reports (27, 28, 29) suggested the degree of information available was a major factor in NPL listing of mining sites, they presented no data showing that the relatively larger data bases for certain mining sites resulted in unfair scoring.

(3) The TRC reports (27, 28, 29) also suggested the final HRS score for mining sites could be predicted by population alone. Since the TRC reports only addressed mining sites, they could not prove a bias against mining waste sites.

Nevertheless, the Subcommittee believes the present HRS is not well suited for scoring potential releases from mining site wastes because mobility and concentration are not included. Therefore, the present scoring system has a potential to treat mining wastes with systematic error.

For the ground water pathway, the concentration of a constituent in a waste is of much less importance than the concentration of that constituent in the leachate produced at the site. Consequently, more emphasis should be placed on the partitioning of hazardous constituents between the waste and the leachate. Leachate concentration or interstitial pore water concentration, either known or estimated, should then be factored into the waste quantity term in the HRS. For wastes which are not in solid form, total contaminant mass quantity should continue to be used.

Improved ways of considering the concentration, toxicity (inorganics have special characteristics), release (mobility in various matrixes), and information on the transport/transformation of chemicals would make the HRS more accurate. The area of contact of the site with the environmental compartments (air, water, humans, etc.) is also an important factor.

The issue of mobility is especially important at mining sites because the large volume of mining wastes often means large masses of the contaminant are available for release. However, certain conditions must exist for these releases to occur. The current HRS does not address specific ionic form of inorganic metals, and ion form affects mobility.

Because mobility is a more discriminating concept than persistence in the subsurface, the Subcommittee suggests that OERR explore means of incorporating important matrix characteristics in a revised HRS. Such characteristics include extreme acidity or alkalinity (as expressed by both high and low pH), any crystalline phase modifications of mining wastes that differ from native geologic materials, and the sorptive capacity of surrounding geologic materials. The latter influences migration tendency.

With respect to the feasibility of using concentration data in the revised HRS, the Subcommittee finds that including hazardous constituent concentration is desirable because both the severity of observed releases and the risk of potential releases are related to concentration.

EPA has proposed two options for modifying the HRS to account for the concentration of hazardous constituents. Both approaches translate waste constituent concentration data into an estimate of the total mass of a hazardous constituent at the site, which is then used to compute the waste quantity score for the HRS. Even the approach which uses "total mass" of hazardous constituent could contribute to produce false positives for some large volume wastes and pathways.

The Subcommittee's preferred approach (Option 3) encourages the use of concentration data and provides the flexibility to substitute indirect estimates such as default concentrations to estimate a constituent's total mass when direct measurements of concentrations are not available. While the direct measurement approach (Option W2) provides the soundest scientific basis for the HRS is most cases, it may not be practical, due to safety and cost considerations for every site at the site inspection stage. The Subcommittee suggests the direct use of concentration rather than conversion to a mass value.

A method of determining a "representative concentration" for a site based on a stratified sampling strategy would be useful. In this approach, a complex site could be subdivided into a set of more homogeneous regions or strata, and a representative value for each stratum determined through limited sampling. Statistical techniques exist for manipulating stratified data, which could then be recombined with appropriate weighting into a final single HRS score for the site.

Exposure

To the extent that the HRS is intended to assess relative risk, it must address both toxicity and exposure sufficiently.

Exposure occurs when there is contact between pollutants and receptors. It is important to address exposure when there are toxic chemicals present in order to determine whether there is any actual or potential risk to health or the environment. Where there are no toxic substances or where there is no exposure, there is no risk, even though there may be release or contamination. (However, determining the existence of a release or of environmental contamination is often the first step in evaluating actual exposure.) Where there is incomplete information on either toxicity or exposure, risk cannot be fully assessed. Risk can be evaluated by assessing four parameters: (a) the presence of chemicals, (b) their potential for release and mobility, (c) the probability of contact with humans, plants or animals and (d) their intrinsic toxicity.

Much could be gained by adding a chemical-specific exposure score that could be combined with chemical-specific toxicity scores to evaluate which chemicals dominate the risk at a single site and how the risk might compare across sites that are otherwise similar.

Given some minimal information about a site and its chemical inventory, it may be possible to make crude estimates of partitioning among environmental media and, therefore, of emissions by route which could be used to generate part of a chemical-specific exposure score. The following information would support development of a chemical-specific exposure score:

1. An estimate of the total mass or source concentration of important chemicals at the site.

2. A description of the site-specific factors influencing release, e.g.; impoundment vs. landfill.

3. Partition factors applicable to the chemical, e.g. Henry's Law constant and organic carbon partition coefficient.

Some characterization of the potential for migration also allows better consideration of time as a factor in site management.

Environmental pathways include air, water (both ground and surface water), soil, and plants and animals that become part of the human food chain. The potential for release and mobility of chemicals through these pathways affects risk estimates. Chemicals behave differently in different environmental pathways, so all pathways need to be evaluated to estimate risk effectively.

The main difficulty of dealing with exposure directly is that we are dealing with potential exposure as well as actual exposure. There are two aspects of exposure to be considered--the concentration of contaminants in the environment around the site and the number of people potentially exposed to these concentrations. Actual release may be demonstrated by environmental sampling. Potential release may be addressed by considering properties of the site and characterisitics of the chemicals present, such as distance to ground water and volatility. Similarly, the number of people (receptors) present and actually exposed today can be counted, while the number of people who might be present at the location in the future can only be estimated from studies of population dynamics.

Measurement of exposure may be person-based or community-based.

While estimates of individual person-based exposures can be developed from biological samples, from personal household samples, from self-reported exposures, and from self-reported symptoms, each approach has its limitations.

Community-based exposures can be developed from ambient pathway measurements, from site measurements, and from modeled exposures. Numerous assumptions about targets and behavior are needed to impute exposure from ambient pathway measurements. However, even more assumptions are needed to impute exposure from site measurements.

Incorporating concentration and mobility could produce a more comprehensive site assessment procedure. One way to do this is by using concentration as a weighting factor for the waste quantity. The resulting effective waste quantities for low volumes of high concentration waste might be similar to those for large volumes of low concentration wastes. Similarly, the scores for toxicity/persistence and for effective waste quantity could be adjusted by considerations of mobility.

Algorithm

Improving the algorithm could potentially do more to improve the HRS than fine-tuning individual components.

The Subcommittee has recommended changes that will allow the HRS to provide a more accurate and scientifically based estimate of the relative risk of candidate sites. To the extent possible, the HRS scores should correspond to an objective analysis of relative risk at sites. However, this is not always feasible due to both scientific and data limitations, as well as the value and policy decisions implicit when considering and balancing human health and environmental impacts.

A revised HRS, better designed to evaluate sites by relative risk, will provide an improved mechanism for determining which sites should be included on the NPL, and can potentially provide meaningful input to the subsequent prioritization of NPL sites. However, the Agency must continue to base this prioritization on many factors in addition to the HRS. Most of the changes needed to transform the current HRS into a system more reliably related to risk are changes in the overall algorithm and not changes with vast new data requirements.

Internal consistency is important. Making rules that are consistent requires little up-front investment and no additional costs in the scoring of specific sites. These changes can be more cost-effective than some improvements to portions of the HRS alone, especially ones requiring additional data collection.

The way that various components of the score are combined should reflect how their real world counterparts interrelate. The approach for accomplishing this is to begin with a physically-based exposure assessment model for each exposure pathway, structured to properly translate expected or potential releases into environmental concentrations and subsequent exposures and effects. These models would, of necessity, be highly simplified for a screening assessment. Even a simplified exposure assessment model may not be feasible given the time, resource and data limitations associated with the HRS process. However, the manner in which the pathway scores are estimated and combined should be consistent with the fundamental material balance and exposure principles of such an underlying model. This can be accomplished in the context of the structured value approach used in the current HRS system.

When there isn't "enough" data for the HRS, it is necessary to have a default value that encourages data collection (also termed missing value replacement). Lacking complete information on chemical inventory and concentration at a site may well be the rule rather than the exception. Therefore, a minimum data requirement will reduce the inconsistencies that are otherwise inevitable when different people perform the scoring.

One concern with the use of default data is that the fact of data limitations could indicate that the site might be different from otherwise comparable sites. The definition of comparable sites is crucial and may depend on the scoring component.

When data are available that exceed what is needed for the HRS, there is the question of how to use all of it. The default or tiered approach OERR presented on concentration is one mechanism for using additional data in the revised HRS. Another approach is the assignment of discretionary points. The Subcommittee discussed several scenarios where discretionary points could be assigned including sites where: a very large number of chemicals were identified, the presence of the toxic materials in the surrounding population had been demonstrated, and toxic particulate air emissions were anticipated. For the HRS score to reflect relative risk, the extra points assigned must be proportional to the extra risk the situation presents. (See Appendix 5.)

Recommendations to Evaluate and Improve the HRS

The current HRS is appropriate for the original purposes OERR has described because most of the factors scored are related to risk, and higher scores for those factors reflect higher risks. Thus, the current HRS is plausible. However, it is both possible and desirable to revise the HRS to relate more closely to the relative risk posed by uncontrolled waste sites.

The HRS performance should be judged by an empirical retrospective evaluation of how successfully the HRS predicts risk or on how successfully its components predict phenomena (such as release) which contribute to risk. This evaluation should be based on an in-depth technical review. Whatever the definition of risk, the HRS should be judged on how well it approximates that definition, not on how well it matches a subjective notion of the relative importance of the sites in a test set.

The Subcommittee recognizes the possibility that sites containing hazardous chemicals whose toxicity is not widely known will be omitted from the NPL listing, thus possibly creating false negatives. Measures to counter this problem include continuing to develop toxicity profiles on more chemicals and keeping good records so that sites with currently unstudied chemicals can be re-evaluated as toxicity information on these chemicals becomes available.

The Subcommittee recognizes the need for some flexibility in the HRS to allow for the wide range of physical and chemical characteristics of sites. Being flexible is compatible with reducing the possibility of error in the HRS. EPA must reduce this possibility of error in each component (or "factor") of the system and, even more importantly, in the algorithm used to relate these components into a score that is intended to reflect relative risk.

To adequately evaluate the current or modified HRS, in-depth studies should be conducted to determine the effectiveness of the HRS to assess risk and to identify areas for improvement. One goal of these studies would be to improve the algorithm so that it can be defended as risk-related. Another goal is to to determine at least a crude method for estimating the quantity of specific chemicals present. Any HRS evaluation studies should be thoroughly peer reviewed before their initiation.

Future evaluation of the HRS should consider the possibility of incorporating detailed numerical geochemical transport/fate models which are currently under development. The advantage of using such models in a future HRS is the explicit inclusion of quantitative representation of specific processes and mechanisms reponsible for the release, transport, transformation, and retention of hazardous compounds. In comparison to structured value (or "scoring") approaches, the models increase data requirements, but can yield less ambiguous, more detailed simulations appropriate for pathway calculations and, ultimately, exposure estimates.

As mentioned in the Other Comments portion of Appendix 3, EPA should develop studies both to review large-volume waste sites ranked under the model and to examine basic parameters of the model.

APPENDIX 1

REPORT OF
THE TOXICITY FACTOR WORK GROUP
TO THE
HAZARD RANKING SYSTEM SUBCOMMITTEE
OF THE
SCIENCE ADVISORY BOARD

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U. S. ENVIRONMENTAL PROTECTION AGENCY
SCIENCE ADVISORY BOARD
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
TOXICITY FACTOR WORK GROUP

ROSTER

CHAIRMAN

Dr. Warner North, Principal, Decision Focus Inc. Los Altos Office Center
Suite 200, 4984 El Camino Real, Los Altos, California 94022

MEMBERS/CONSULTANTS

Dr. Paul Deisler, 11215 Wilding Lane, Houston, Texas 77025

Dr. John Doull, Professor of Pharmacology and Toxicology,
University of Kansas Medical Center, Kansas City, Kansas 66103

Dr. Joseph V. Rodricks, Environ Corporation, 1000 Potomac Street, N.W.,
Washington, DC 20007

Dr. Ellen Silbergeld, Chief Toxics Scientist, Toxic Chemicals Program,
Environmental Defense Fund, 1616 P Street, N.W., Room 150,
Washington, D.C. 20036

Dr. Rebecca T. Zagraniski, Division of Birth Defects and Developmental
Disabilities, Center for Environmental Health and Injury Control,
Centers for Disease Control, Koger Center, Room 2008 (F-37),
1600 Clifton Road, N.E., Atlanta, Georgia 30333

EXECUTIVE SECRETARY (Until August 31, 1987)

Mr. Eric Males, Executive Secretary, Science Advisory Board (A-101F),
U.S. Environmental Protection Agency, 401 M Street, S.W.,
Washington, DC 20460 (Until August 31, 1987)

EXECUTIVE SECRETARY (After August 31, 1987)

Mrs. Kathleen W. Conway, Deputy Director, Science Advisory Board, (A-101F),
U.S. Environmental Protection Agency, 401 M St., S.W.,
Washington, D.C. 20460

STAFF SECRETARY

Mrs. Dorothy M. Clark, Staff Secretary, Science Advisory Board, (A-101F)
U.S. Environmental Protection Agency, 401 M Street, S.W.,
Washington, DC 20460

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ATTACHMENT: Discussion of Options for Revising the Hazard Ranking System (HRS) Toxicity Factor, May 4, 1987 pages 40-41

GENERAL COMMENTS

The Toxicity Factor Work Group reviewed Discussions of Options for Revision of the Hazard Ranking System (HRS) Toxicity Factor (12).

The Toxicity Factor Work Group believes that toxicity is an important consideration in assessing sites because, if the objective of the HRS is to generate estimates of relative risk, the HRS must deal with toxicity and exposure. The toxicity factor in the current HRS makes distinctions among only a few of the 951 current and proposed site on the NPL. By pathway, fully 85% (ground water), 87% (surface water), and 97% (air) of these sites received the maximum toxicity/persistence score. Because the Agency did not present information on sites that are not on the NPL, the Work Group was unable to determine whether the current toxicity factor is adequate to distinguish between "very toxic" and "not so toxic" sites. Not only is it unlikely that the most toxic substances at different sites are equally toxic, it is inconceivable that they occur at equal concentrations even if total quantity of waste is identical. Therefore, in revising the HRS, the EPA should consider approaches that would better discriminate between sites of differing toxicities and subsequently examine how well the new toxicity factor actually performs.

Some toxicity decisions are made in the Preliminary Assessment/Site Investigation (PA/SI) stage. For example, specific chemicals are selected for scoring in the HRS, while other chemicals are dropped from the process. The bases for these selections do not appear to be standardized at this time. As a result, while the toxicity data that is handled by the HRS is already a subset of the full information, additional (perhaps important) toxicologic data are not part of the quantitative process. The exposure factors are addressed in various ways in the HRS and most are handled quantitatively in the HRS. Consequently, the HRS score actually reflects a disproportionate amount of information on exposure and less on toxicity, thus deemphasizing toxicity in the final score. Therefore, EPA should consider the development of some type of consistent methodology or guidelines for evaluating the toxicity of chemicals at a site during the PA/SI stages.

The Toxicity Factor Work Group reviewed the following methods (12) for evaluating the toxicity of individual chemicals:

- o Chronic Toxicity (Noncancer)
  - Reference Dose Method
  - Reportable Quantity (or Composite Score) Method
  - Modified Acceptable Daily Intake (ADI) Method
- o Carcinogenicity
  - Cancer Potency Factor Method
  - Reportable Quantitites (RQ) or Effective Dose$_{10}$ Method
  - EPA Weight-of-Evidence Method
- o Acute Toxicity
  - Reportable Quantities (RQ) Method
  - Registry of Toxic Effects of Chemical Substances (RTECS) Method

The Sax chemical toxicity ratings have provided a very crude basis for prioritizing sites because they are largely based only on the acute toxicity of one constituent of the waste. The Sax system is insufficient because it focuses on acute adverse outcomes instead of the range of toxicological endpoints that need to be addressed in the HRS and because it does not provide citations so that toxicologic ratings can be reevaluated and verified for the purpose of the HRS.

OERR presented three options for evaluating and scoring toxicity in the revised HRS (12). These are a reportable-quantities-based option (E1), an option based on reference doses and potency factors (E2), and an option based on modified acceptable daily intake and weight-of-the-evidence approaches. Each of these options takes into account several types of toxicity and uses quantitative measures of substance potency, whereas the Sax method is unidimensional and developed for protection against poisoning. The three options presented by OERR are much better than the Sax rating method, and the Work Group recommends that EPA replace the Sax method.

Because OERR's three options make use of essentially the same data bases for toxicity (although the data are processed differently), the Work Group does not believe any of the options is overwhelmingly superior to the others. The options do have different strengths and weaknesses, however, and the Work Group has addressed these below in (page A1-5).

Although this is really a policy decision rather than a scientific one, the Work Group does not encourage a system for weighting the severity of different health endpoints, as is currently done for calculating reportable quantities (RQs), both because such weightings are subjective, and because they are subsequently obscured by the final numerical score.

Similarly, to the extent that scientifically legitimate techniques exist for the consideration of various toxic effects in man and in nature, the decision of which endpoints to address is primarily a science policy decision rather than a purely scientific one. Nevertheless, because there are many endpoints relevant to human health and the environment for which good methods exist, the Work Group encourages the Agency to address multiple endpoints as part of the HRS toxicity factor.

The Work Group's efforts to review the toxicity issues were complicated by the following factors.

- It is difficult to translate the objectives of the HRS (that is, a scheme that separates sites into those with risks greater or lesser than an arbitrary threshold, with a desire to avoid false negatives [false placement of high risk sites into the low risk category], and to the extent possible, that ranks all sites by their relative risk) into operational criteria to design the scheme.

- The Agency has presented the toxicity issues in a somewhat theoretical manner. Few real world examples and few test cases such as example rankings of chemicals or sites, were presented to the Work Group.

- Lastly, and probably most important, the Work Group believes that toxicity issues are integrally linked to dose (i.e., migration and exposure) issues. The existing HRS system deals with exposure by using surrogates to address the question of whether people (receptors) will be exposed, and if so, how many will be exposed, and to what concentrations, via ground water, surface, and air routes.

RESPONSES TO SPECIFIC TOXICITY ISSUES POSED BY OERR

The full text of the specific questions can be found in the attachment to this report. They are repeated in abbreviated form here for the convenience of the reader.

How Many Chemicals Should Be Evaluated?

A review of past Superfund risk assessments were undertaken by OERR (10) to determine whether the health risk associated with a site is likely to be dominated by one or a few chemicals (for each pathway), or by a larger number of chemicals. The study, which was limited in the number and type of sites considered and because sites were selected for convenience rather than for representativeness, generally indicated that only a few chemicals would dominate at any given site. However, the Work Group did not review this study in detail and cannot recommend a fixed number of chemicals for OERR to examine at each site. Instead, the Work Group offers the following general guidance.

EPA appropriately considers toxicity early in the site evaluation process. Identification of known toxic substances occurs in the PA/SI stages prior to the HRS evaluation. Indeed, only sites containing toxic substances currently identified by the Superfund Laboratory Program are likely to be candidates for HRS evaluation and listing. In addition, the chemical receiving the highest score in the toxicity-persistence matrix (8) is selected by field staff for scoring purposes in the HRS. The Work Group has concerns about the procedure now used to identify chemicals in the PA/SI stages and to select a single "most toxic" chemical for the HRS evaluation.

Because so few chemicals have been toxicologically well characterized, the Agency should consider a factor for sheer numbers of chemicals known to be present (in addition to developing scores based on a smaller number of chemicals of known toxicity). All things being equal, a site with more chemicals should receive a higher priority for further evaluation, most probably in the RI/FS. (See discussion of discretionary points in Appendix 5 of the HRS Subcommittee's report.)

Should Separate Toxicity Ratings for a Chemical be Developed for Various Exposure Routes?

Because this question is inextricably related to how the HRS deals with migration and exposure issues, the Work Group has chosen to discuss the advantages and disadvantages of three approaches rather than to make a single recommendation.

One approach is to aggregate route-specific exposure scores into a net (total) exposure score for a site. This total exposure score could be multiplied by a net toxicity score. The toxicity score may not need to be route-specific because the cruder the scheme, the less the need for route-specific factors.

A more accurate analysis would independently evaluate route-specific risks before aggregating. Because the relationship between exposure level and the biologically effective dose is different for different pathways, route-specific toxicity factors would improve the accuracy of such an approach.

A third approach, which recognizes that route-specific toxicity factors are not yet available for a large number of compounds, is to use route-specific information when it is available and relevant--such as in the case of asbestos where the inhalation route has far greater biological effect than the ingestion route--and to aggregate exposure scores where such information is lacking or the route-specific differences are small.

Whether or not route-specific toxicity is addressed in the HRS, it should be considered in the Remedial Investigation/Feasibility Study (RI/FS) stage because the more detailed information supports more realistic analysis of risks.

How should potential carcinogens, noncancer effects and acute toxicity be evaluated as part of a scoring system used to determine listing on the NPL?

The Work Group concludes that multiple measures of toxicity should be used in the process of evaluating waste sites because a variety of toxic effects may be experienced by the exposed human and natural populations. Which endpoints are of concern to EPA is primarily a science policy decision. However, scientific techniques exist which would permit the HRS to consider several endpoints which are relevant to human health and the environment.

The Work Group believes the importance of acute effects in the HRS should be decreased relative to chronic effects because, given the likelihood for long-term low-level exposures around uncontrolled waste sites, chronic effects appear more relevant. Futhermore the Work Group understands that EPA has a separate emergency response program to respond quickly to those uncontrolled waste sites where acutely toxic exposure levels are thought possible. As a result, the Work Group recommends replacing the Sax method with any of several OERR-developed approaches which include measures of chronic toxicity.

Acute effects are important when they occur, and some Subcommittee members conclude that, since the emergency program suffices to address them, acute effects need not be considered in the revised HRS. However, because of reports of acute effects such as odors, nausea, headache, and respiratory irritation around unremediated and uncontrolled hazardous waste sites and because of the potential for catastrophic releases, or releases during remediation which may result in exposures sufficient to cause acute effects, the Work Group recommends that the revised HRS include acute effects among the multiple endpoints considered.

Besides carcinogenicity, the health endpoints should include those used to establish reference doses (including at a minimum, fetotoxic, teratogenic, and neurotoxic effects); and acute toxicity (including not only lethality, but endpoints such as irritation, allergic sensitization, and neurotoxicity). The major concerns for most sites will be for chronic health effects (cancer and non-cancer). While acute toxicity should be examined, it will generally be less important than chronic toxicity in the site ranking process. Any of the variety of health and environmental endpoints considered could motivate a more detailed evaluation of a site.

For acute toxics, the Work Group prefers the Registry of Toxic Effects of Chemical Substances (RTECS) method to the Reportable Quantity (RQ) method because RTECS facilitates route-specific toxicity ratings and closer attention to the raw toxicity data. If a more sophisticated use of the toxicological data is envisioned, use of the RQ evaluations of RTECS may be helpful to identify the preferred animal studies for toxicity ratings. Use of Threshold Limit Values (TLVs), which are contained in RTECS, may be one means of expanding the acute toxicity, including not only lethality but also other endpoints.

For non-cancer chronic effects the Work Group prefers the Reference Dose (RfD) method because the RQ method involves subjectively weighting the severity of various endpoints and the modified ADI method has not received extensive review and may differ from the RfD method in rating individual chemicals.

For carcinogenic potency the Work Group does not perceive much gross difference between the two options presented (q_1* vs. ED10). Other measures (e.g., ED [1] and ED [0.1]) should be investigated because they refer to a more realistically meaningful risk range for human exposures and, where the dose-response is known to be concave upwards, they would offer an automatic correction to potency for this fact. In evaluating relative risk for carcinogens, both weight-of-evidence and potency should be considered in determining relative risk for carcinogens.

The Work Group judges that the Agency's procedure in the RQ calculation for combining weight-of-evidence and potency information is reasonable for purposes of ranking different carcinogens.

Are There Scientific Advantages/Disadvantages to Basing a Toxicity Ranking Method on a No-Adverse-Effect Level?

The Work Group chose to address the advantages and disadvantages of the options presented rather than enter into an abstract discussion on NOAELs and alternatives. For non-cancer chronic effects the Work Group prefers the Reference Dose (RfD) method to the Reportable Quantities (RQ) method (which involves weighting the severity of various endpoints), and to the modified Acceptable Daily Intake (ADI) method (which has not received extensive review and may differ from the RfD method in rating individual chemicals).

Is it Necessary to Attempt to Develop Default Values for Rating a Substance´s Toxicity When its Toxicity Data Base is Limited?

The Work Group has no recommendation on this issue. Having little patience with "invented toxicology" the Work Group wishes to encourage the Agency to develop data rather than relying on default values. In cases where toxicological data become available after a site has been scored, the Work Group encourages the Agency to re-evaluate the site in the light of the new findings.

What Quantitative Procedures are Most Reasonable for Combining Individual Toxicity Ratings for Multiple Substances at a Site?

The Work Group does not encourage a system for weighting the severity of different health endpoints, as is currently done for calculating Reportable Quantities (RQs). The Work Group believes that a variety of endpoints should be used to rank sites for further study. In the context of an on/off switch, any health effect may be an adequate criterion for further study of a site.

OTHER COMMENTS

Flexibility and Common Sense

The HRS is designed to be a simple, workable, mechanistic procedure that generates reliable estimates of relative risk. However, considering the state of information available at the PA/SI stage, the complexity of risk, and the variability among sites, this may be an impossible goal. In light of these uncertainties, there are many opportunities for errors in both overestimating and underestimating relative risk. Thus, the Work Group believes that any system must offer flexibility and the opportunity for common sense.

General Support for a Structured Value Approach to the HRS.

Even though, in the Work Group's view, it may not be possible to develop an HRS that provides reliable estimates of relative risk, the Work Group is supportive of a HRS concept and role which attempts to rank sites by relative risk. That is, the Work Group supports the use of a structured value analysis that includes (even if crudely) factors related to risk. The estimates generated by such a scheme may be simply one mechanism for evaluating sites.

Two Additional Steps in the NPL Process

The Work Group has discussed the need for two additional steps in the NPL process: (a) some type of consistent methodology or guidelines to select chemicals during the preliminary assessment and site investigation should be developed for use in the site evaluation process, and (b) the option of using more detailed risk information, if available, should be considered as a supplement to the HRS process. One approach, for example, is to allow adjustment of point scores to take into account special knowledge, as discussed in Appendix 5 to the Subcommittee's report.

Migration

Migration of pollutants from a site to a receptor (considering both time and kinetics) is an important part of the exposure assessment. Where there is no contact between pollutants and receptors, there is no risk. The current HRS does not evaluate mobility at all and does not sufficiently evaluate migration (which the current HRS addresses in the ground water, surface water and air pathways) and, thus, can be expected to misclassify some sites with respect to relative risks.

Dose

Dose information is included in the HRS evaluation only through the very crude surrogate of total waste quantity. Concentration information for specific substances, if available, is not used in the HRS. The Work Group is concerned about dose as it relates to the types and severity of effect. It is an important element for predicting risk, but it is not apparent that any effective surrogates exist to address it in the current HRS.

Future Studies

Some members of the Work Group are concerned that sites containing hazardous chemicals whose toxicity is not widely known will be omitted from the NPL listing, thus creating false negatives. Measures to counter this problem include continuing to develop toxicity profiles on more chemicals and record keeping so that sites with "unknown chemicals" can be re-evaluated as toxicity information on these chemicals becomes available.

The lack of toxicological information on many chemicals is hardly a problem unique to the Superfund program and the Work Group does not wish to imply that this difficulty can be solved by Superfund, or indeed the Agency, alone.

SPECIFIC QUESTIONS FOR THE SCIENCE ADVISORY BOARD

This section lists a few specific unresolved questions about scientific issues involved in the development of a revised toxicity factor for the HRS. EPA believes that these questions are significant and need to be addressed before a revised toxicity factor can be developed.

(1) How many chemicals per site (or exposure medium) should be evaluated to serve as the basis for an overall toxicity factor score? If less than all chemicals detected, how should they be selected? Should selection be based on the most toxic substances, the most frequently detected, or those that appear to be present in the greatest quantities?

(2) Should separate toxicity ratings for a chemical be developed for various exposure routes (i.e., should chemicals have three or four different ratings, depending on exposure route?) , or is a single route-independent toxicity rating adequate for HRS ranking purpose? [Note: It is assumed that separate media-specific toxicity factor scores would be developed for a site under any HRS revision option based on the chemicals evaluated for that medium, regardless of whether route specificity is accounted for in individual chemical toxicity ratings.]

(3) Should potential carcinogens be evaluated for noncancer effects also, or can it be assumed that the carcinogenicity potential should dominate the overall toxicity rating?

(4) Is it advisable to include acute toxicity evaluation as part of a scoring system used to determine listing on the National Priorities List (NPL)? If so, how should it be weighted?

(5) Should more specific noncancer toxicity types, such as teratogenicity and mutagenicity, be broken out and rated separately? If so, how should they be weighted relative to other effect types so that single overall rating could be derived for each chemical?

(6) Are there scientific advantages/disadvantages to basing a toxicity ranking method on a no-effect level NOAEL, such as in Options E2 and E3 versus an effect level (MED, such as in Option E1)?

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(7) It is necessary to attempt to develop default values for rating a substance's toxicity when its toxicity data base is limited, or should site scores be developed based only on chemicals having "better" toxicity data?

(8) What quantitative procedures are most reasonable for combining individual toxicity ratings for multiple substances at a site?

APPENDIX 2

REPORT OF
THE AIR TARGET DISTANCE WORK GROUP
TO THE
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
OF THE
SCIENCE ADVISORY BOARD

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U. S. ENVIRONMENTAL PROTECTION AGENCY
SCIENCE ADVISORY BOARD
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
AIR TARGET DISTANCE WORK GROUP

ROSTER

CHAIRMAN

Dr. Thomas Burke, Deputy Commissioner, New Jersey Department of Health
Room 805, State Health CN360, Trenton, New Jersey 08625

MEMBERS/CONSULTANTS

Dr. Stephen L. Brown, Project Manager, Environ Corporation
1000 Potomac Street, N.W., Washington, DC 20007

Dr. Shepherd Burton, Systems Applications, 101 Lucas Valley Road
San Rafael, California 94903

Mr. George F. Carpenter, Michigan Department of Natural Resources,
Environmental Response Division, Post Office Box 30028
Lansing, Michigan 48909

Dr. Naihua Duan, Statistician, Rand Corporation, 1700 Main Street,
Santa Monica, California 90406

Dr. Donald Mackay, Department of Chemical Engineering and Applied
Chemistry and Institute for Environmental Studies,
University of Toronto, Toronto, Canada M5S 1A4

Dr. Mitchell Small, Department of Civil Engineering, Carnegie Mellon
University, Schenley Park, Pittsburgh, Pennsylvania 15213

EXECUTIVE SECRETARY (Until August 31, 1987)

Mr. Eric Males, Executive Secretary, Science Advisory Board, (A-101F),
U.S. Environmental Protection Agency, 401 M Street, S.W.,
Washington, DC 20460 (Until August 31, 1987)

EXECUTIVE SECRETARY (After August 31, 1987)

Mrs. Kathleen W. Conway, Deputy Director, Science Advisory Board, (A-101F),
U.S. Environmental Protection Agency, 401 M St., S.W.,
Washington, D.C. 20460

STAFF SECRETARY

Mrs. Dorothy M. Clark, Staff Secretary, Science Advisory Board, (A-101F),
U.S. Environmental Protection Agency, 401 M Street, S.W.,
Washington, DC 20460

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GENERAL COMMENTS

The Air Targed Distance Work Group reviewed OERR's Analysis of the Air Target Distance Limit in the Hazard Ranking System (9).

The air pathway in the current Hazard Ranking System (HRS) uses an evaluation of exposed population at risk to derive a score for "air targets." The scheme uses a matrix of population versus distance for four concentric circles (with radii of 1/4, 1/2, 1, and 4 miles). Public comments have suggested that the four mile distance may be too large. EPA studies, by contrast, have suggested that, for sites with large emission rates of carcinogens, individual lifetime risks may remain above 10^{-6} for even greater distances. The Work Group considered this and other questions related to the air pathway (see Attachment A).

In general, there may not be significant air risks at many potential Superfund sites, but the HRS needs to address them when they are present. The Work Group is very supportive of OERR's efforts to modify the air pathway so that it considers potential releases, instead of relying solely on a score for observed releases. Because air emissions are often episodic or narrowly focused along a particular wind direction, they are difficult to observe. In addition, there can be a declining or changing risk depending on the nature or integrity of containment or the site type. There may have occurred a significant release early in a site's history which has resulted in a loss of contaminants and decreasing emissions at the time when sites are evaluated and scored. Lastly, future activities at a site (such as excavation) may create the potential for new air emissions. For these reasons, inclusion of a potential for release is an important modification of the HRS.

Ideally, if comprehensive information was available, air emission models developed for other purposes could be used to estimate potential releases. These estimations, however, may require information which is not available to the Agency during the preliminary assessment/site investigation (PA/SI) stage. With information on the identities of chemicals present, an emission rate can be calculated for volatile chemicals or the presence of volatile emissions established on a crude yes/no basis. When such information is lacking, volatile air emissions cannot be predicted at all, and the subsequent consideration of air exposure routes is very weak.

If the identities of chemicals are known, it should be possible to modify and simplify the procedures for modeling air emissions from hazardous waste transport, storage and disposal facilities (TSDFs) to calculate an approximate, order-of-magnitude emission rate for impoundments and landfills. Other investigative techniques could be used to confirm emission rates, the most obvious of which is air concentration measurement in the immediate vicinity of the source. Because of the dificulties in measuring variable low-level ambient air concentrations, more direct sampling, such as soil gas analysis or "inverted dish pan" surface sampling, should be considered.

COMMENTS ON THE ISSUES RAISED BY OERR

The full text of the issues raised by OERR can be found in Attachment A. Abbreviated versions are used here for the convenience of the reader.

An Alternative to the Use of a Single Target Distance Limit at All Sites.

The Work Group recommends that EPA consider an alternative to the use of a single air target distance limit for all sites.

To evaluate the exposed population at risk more accurately, the Work Group recommends that the Agency derive a scoring system that will properly weight the number of exposed people according to the distance from the site at which they live. The weighting factor should be proportional to individual risk, as determined by concentrations that decrease with distance from the site. In other words, the system should use population rings that are based on distances from a site at which air concentrations decrease by a constant factor. These distances may vary by size and type of site. For illustrative purposes a method of developing these rings is presented in Attachment B. Although this method does not evaluate maximally exposed individual (MEI) risks *per se*, it does explicitly account for the higher exposures that will occur within the ring closest to the site. Therefore, the Work Group concludes that a separate or additional evaluation of MEI risks as part of the HRS is unnecessary.

These rings could be incorporated into the scoring system as a simple refinement of the current matrix, as illustrated in Table 1.

Table 1
Suggested Matrix for Air Pathway Population Scores

	Generalized Target Distance Score Distance from Center of Site			
Population	$a-ba$	$ba-b^2a$	b^2a-b^3a	b^3a-b^4a
10^6-10^7	10	9	8	7
10^5-10^6	9	8	7	6
10^4-10^5	8	7	6	5
10^3-10^4	7	6	5	4
10^2-10^3	6	5	4	3
10^1-10^2	5	4	3	2

The matrix is interpreted as follows. The distance "a" is the radius of the site itself. (In practice, sites will not be circular and "a" must be taken as a typical dimension--derived, for example, by taking "a" as equal to the square root of the area of the site divided by pi.) The dimensionless constant "b" is a multiplier of the order of 2 to 4, determined as shown in Attachment B. For example, if the site was 200 yards in diameter (about 1/9 mile), and the multiplier was 3, the rings would be 1/9 to 1/3 mile, 1/3 to 1 mile, 1 to 3 miles, and 3 to 9 miles. The population used is that in each annular ring (between "a" and "ba", etc.), determined to one significant figure. Once scores are assigned for each ring, the largest score is taken as adequately representing the site. The scores are all logarithmically related to population risk, so that they should be added to other scores representing logarithms of variables that enter risk linearly, such as the carcinogenic potency or the quantity of waste or emission rate.

As shown, the scores for a large site ("a" is large) will be greater than for a small site ("a" is small) for the same population distribution because each of the four rings will be larger and incorporate more population. The population in each ring will increase as a^2, so if a increases by a factor of 3, the population will expand by a factor of 9, and the score will go up by one point. This behavior implies incorporation of a factor related to emission strength (in turn, proportional to a^2) in the score. This may not be appropriate. Perhaps it would be better to define a standard value for a, taken from a typical site.

After deriving such a ring-weighted system, the Agency may want to evaluate the effects of different diameters to see if the use of a single diameter for all sites is reasonable because a ring width that varies between sites, based on their diameters, may be too complex for the HRS.

To place the scores from the ring-weighting process on the same scale as other scores in the HRS with which they might be combined, the scores could be increased in direct proportion by multiplying by a constant. For example, if one wishes to have a score of 30 in the top left corner, one can multiply all the scores by 3 thus obtaining, for example, 3 in the lower right corner and 12 in the lower left corner. But if this is done, an order of magnitude change in carcinogenic potency should also be represented by 3 points change in score, and so on.

The above scoring system is reasonably precise for cancer for which individual risk, given the usual assumption that risk is directly related to average lifetime concentration in air, is directly related to average lifetime concentration in the air. For noncancer effects, EPA ordinarily assumes a threshold of concentration for any damage to occur. Thus, outside some critical distance (different for sites with different emission rates or different threshold toxicities), no effects will occur, and inside that distance one could assume conservatively that 100% incidence of the effect occurs. There seems to be no simple scoring scheme to take this property into account in a population score, but the practical effect is that population beyond perhaps one mile (for example) is simply irrelevant to the air target score for noncancer endpoints. If, in the toxicity score, a noncancer effect is responsible for the greater part or the score, then the choice of points from Table 1 should be restricted to the two left columns (for example). As before, the degree of danger for an individual in these two rings will have already been captured in the toxicity score and whatever score is used as a surrogate for exposure.

Approach to Assessing Health Risks

As implied above, toxicity considerations may also be different for the air pathway than for surface or ground waters. An exclusive evaluation of a contaminant from the standpoint of carcinogenicity is inadequate. Many compounds detected at contamination sites are not currently considered carcinogens or suspected carcinogens. Acute toxicity is generally meant to be considered in emergency or interim response procedures prior to HRS scoring. In reality, sites may not pass some threshold of acute toxicity considered in this way and, yet, still exhibit some subacute or chronic health effect. This is particularly true for the late-history site, where average emissions may be relatively low, but--with breaching of a few drums, deterioration of a building, or removal of cover--a short-term, acute emission is again possible. If acute toxicity conditions were discovered at a site during site inspection or HRS scoring, the site should be automatically referred to emergency response. This seemingly would eliminate the need for considering acute toxicity in the HRS. It does not appear that this complete separation is appropriate, however, given the threshold nature of emergency response or changeable site conditions.

In addition, other subacute or chronic effects of noncarcinogens must be considered. Neurotoxicity and chemosensory effects of air pollutants, while occurring at differing levels of concern, are real responses to airborne contaminants, and environmental toxicity is occasionally important. The public is also often concerned about nuisance effects, such as odor or nausea.

The Work Group favors separate consideration of acute toxicity in a direct contact pathway. However, acute toxicity could instead be included among the multiple measures of toxicity in a revised toxicity factor. In addition, the exposure of the near-site population exposure to air contaminants could be separately assessed, or discretionary points could be added to the HRS score for smells or symptoms reasonably related to exposures to chemicals known to be at the site (providing that these are confirmed in some suitable manner). The direct contact pathway may be especially useful if EPA wishes to eliminate or reduce the importance of scoring acute toxicity for the surface and ground water pathways.

In assessing exposure, consideration of each media pathway is recommended including air, water, food, and direct contact. Measurement of exposure should also consider the route of exposure through which substances exert their effects. For example, inhalation is more important than ingestion in the case of asbestos.

Applicability or Air Emissions Information from TSDFs to Superfund Sites and the Range of Emissions Estimates Calculated

Because air emissions are often episodic or narrowly focused along a particular wind direction, they are difficult to detect. For this reason, inclusion of a potential for release is an important priority for modification of the HRS. The procedures given in the Analysis of the Air Target Distance Limit in the Hazard Ranking System (6) for estimating air emissions from surface impoundments and landfills at Superfund sites are based on model equations developed for RCRA Facilities (TSDFs). These procedures are appropriate for the purpose to which they are applied: to determine the range of possible (long-term) emission rates at Superfund sites. The model equations represent the state-of-the-art in this relatively new area of environmental science.

There are, however, some limitations identified below and suggestions for additional analysis that can result in a clearer and more defensible analysis. These include the need to illustrate previous validation studies of the models, particularly those presented in peer-reviewed scientific journals, the need to better illustrate the model comparisons at existing landfills, and better identification of the potential applicability of the models to particular sites.

Despite the difficulties in data collection, validation studies with the surface impoundment and landfill models have been attempted. Using these studies in the documentation for proposed changes to the HRS would provide the user with a sense of the reliability and accuracy of the procedures, which we suspect is about one-half to one order of magnitude. These studies have been presented in peer-reviewed articles in journals such as Environmental Progress and the Journal of the Air Pollution Control Association.

In addition, the comparison of predicted and measured emission rates (in Section 4.4.1.4 of Analysis of the Air Target Distance Limit in the Hazard Ranking System, July 6, 1987) would be strengthed by inclusion of a plot of predicted vs. observed rates. This comparison may indicate significant variability on a site-by-site basis. This variability is, in part, due to the simplifications inherent in the models, but is also largely a result of the difficulties in identifying model parameters at a given site, even for the most basic of inputs, such as the identification of chemicals in the waste. These difficulties are pertinent to the use of these, or related model equations, as part of an HRS scheme that considers potential air emissions.

Ideally, if comprehensive information was available, the emission models for TSDFs could be used. A brief review of these procedures is presented below in order to highlight important variables.

Emissions from surface impoundments depend on the concentration of chemicals in the water. Methods to estimate such emissions apply the traditional "two phase resistance" transport equations which include an estimate of the chemical's air-water partition coefficient or Henry's Law Constant. The resistances depend on factors such as wind speed, fetch, diffusivities, and the presence of oily films but, to a first approximation, it would probably be acceptable to adopt mean values of the resistances and apply them to all chemicals. The key items of information are chemical identity, chemical Henry's Law Constant, and chemical concentrations. In the long-term the chemical will be depleted from inactive sites unless there is migration from sediments to replace it.

Air emissions from landfills depend on the resistance to transfer from the soil cover depth and porosity, coupled to the chemical's vapor pressure as the driving force for diffusion. The key items are chemical identity, chemical vapor pressure, and soil cover depth and porosity.

Emission rates can be estimated readily for tanks and drums given a knowledge of the geometry and contents. Waste piles and other accumulations of waste will require separate treatment. In all cases, the key variables to estimate volatile emissions are chemical identity and vapor pressure.

Information on the chemical identities is valuable because it allows the presence of emissions to be established and the calculation of emission rates for volatile chemicals. When such information is lacking, air emissions can not be predicted and the subsequent consideration of air exposure routes is impossible These may be evidence of emissions as a result of odors, for example.

If the chemical identities are known, it should be possible to modify and simplify the TSDF procedures to calculate an approximate, order-of-magnitude emission rate for impoundments and landfills. A score could then be assigned based on the logarithm of the emission rate. The population distance matrix discussed earlier includes the effects of dispersion.

Other investigative techniques could be used to confirm the emission rates, the most obvious of which is air concentration measurement. Ambient monitoring, however, is subject to the problem of dilution, as the three examples on the next page show.

If we consider a site 100 m by 100 m emitting 100 kg/year into a wind of average speed 5 m/s, and assume that the air is well mixed at the downstream sampling site to a height of 5 m, then the concentration at that site will be C g/m^3 given by:

$$100 \text{ kg/yr} \times 1000 \text{ g/kg} = 5 \text{ m/s} \times 100 \text{ m} \times 5 \text{ m} \times 31.5 \times 10^6 \text{ s/yr} \times C$$
$$\text{or } C = 1.3 \times 10^{-6} \text{ g/m}^3 \text{ or } 1.3 \text{ ug/m}^3.$$

This low concentration may be difficult to detect quantitatively.

For surface impoundments, it is preferable to measure the water concentration and infer an emission rate. For example, in the above case an emission of 100 kg/yr over 10^4 m^2 would require a concentration of 0.023 g/m^3, assuming an overall water mass transfer coefficient of 0.05 m/h,

i.e., $10^5 \text{ g/y} = 10^4 \text{ m}^2 \times 0.05 \text{ m/h} \times 8760 \text{ h/yr} \times 0.023 \text{ g/m}^3$.

This concentration is a factor of 18,000 greater than the air concentration.

Likewise, if the emission is from soil and we assume an effective diffusivity (corrected for porosity) of 0.01 cm^2/s or 0.0036 m^2/h and a path length of 1 m and area 10^4 m^2, then the effective diffusion volume exchanged is 0.0036 m^2/h x 10^4 m^2/1 m or 36 m^3/h. This is essentially the volume of soil pore vapor released per hour. If the emission rate was 100 kg/yr the concentrations would be 0.32 g/m^3,

i.e., $10^5 \text{ g/y} = 36 \text{ m}^3\text{/h} \times 8760 \text{ h/yr} \times 0.32 \text{ g/m}^3$.

Again, this concentration is a factor of 250,000 greater than in the ambient air and is much easier to measure.

Based on these examples and the Work Group's experience, to detect the presence and amount of emissions it is desirable to analyze at the source, or as close to the source as possible. Once the chemical mixes with the ambient air, it suffers a concentration drop by a factor on the order of 10^4 to 10^6. This may produce ambient concentrations below detection limits.

Thus, there is thus an incentive to use methods of "probing" sources by using, for example, soil gas analysis or "inverted dish pan" surface emission samples. We believe that valuable confirmatory data would be obtained at quite modest cost. These investigative techniques could give direct measurements of emissions rates.

Site investigations of soil, ground water and surface water have been aided by the prior existence of sound analytical protocols for sample collection, storage, and analysis. It appears that insufficient effort has been devoted to developing protocols which are appropriate for air sampling at waste sites. The traditional high volume sampler is often effective, but it is, to an extent, misapplied. More effort should be devoted to developing more subtle, economic and useful air sampling procedures which are specific to the conditions prevailing around waste sites.

Other Factors Affecting the Potential for Release

The following additional factors should be considered in developing the air pathway component of the HRS:

1. The type of containment, i.e., impoundment vs. tanks, and drums vs. encapsulation, should be considered. Also included should be an assessment of the extent to which the containment is likely to be disturbed as part of the remediation process at the site. Sites where more excavation and handling of wastes are required may present a higher potential for air releases.

2. Catastrophic releases may create air emissions. This category could include the susceptibility of the site to flooding, the seismic activity of the area, and the frequency of severe weather, e.g., extremely high winds which can lead to fugitive particulate emissions.

3. Reported incidents by surrounding residents, such as complaints concerning odors, eye irritation, or nausea, may result from air emissions. While, in the absence of air monitoring data, these reports may not be sufficient evidence of a "confirmed" release, such sites should be scored for their potential-to-release.

OTHER COMMENTS

Relationship of Air Pathway to the Rest of the HRS

As part of its revision of the HRS air pathway, the Work Group recommends that OERR assure that the scores assigned for population and distance are consistent with one another and with other scores with which they must be combined, for example, scores for toxicity, waste quantity, or release potential. If the HRS is to represent the relative risk of sites, it must be consistent with the underlying, quantitative relationships of the factors evaluated. Weighting the risk among pathways on an *a priori* basis where, for example, the air pathway might be worth one-half the ground water pathway, is not scientifically justified.

Two aspects of risk need to be addressed. First, risk may be declining or changing depending on the nature or integrity of containment or the site type. There may have been a significant release early in a site's history which has resulted in a loss of contaminants and decreasing emissions in later history (which often coincides with site evaluation and scoring). This earlier release may have been of an acute nature which no longer is detectable or representative of the site.

The second aspect is that the near-site population may be considered to be at greater risk from the air pathway than from the water pathways. Because of the nature of migration of air contaminants (speed of movement and plume entrainment) the population at highest risk may change as atmospheric conditions change.

There may be a need to consider the near-site population as exposed to an independent direct-contact pathway rather than as a subset of the air pathway because acute rather than chronic toxicity may be more relevant and because of the known presence at some sites of chronic toxicants in the form of particulates (such as dusts containing lead). Exposure to the larger respirable particulates can be a very near-site phenomenon, which may be de-emphasized by inclusion in the air pathway with its focus on greater distances. On-site workers (not cleanup staff, but employees at active manufacturing or landfill sites) are also at risk in manners different from long distance populations. Exposures may last for fractions of days but be intense when they occur. Near-site populations are continually exposed to a variety of routes in comparison to single route exposure of remote populations.

Exposure also changes with the nature of contaminant migration. Near a site, the contaminants are more varied as well as at greater concentrations, and there are more routes of exposure. Volatile organic compounds are present and are subject to inhalation. In addition, particulates containing either metals or adsorbed organics tend to deposit near site boundaries and are subject to ingestion and dermal absorption as well as inhalation. Remote from the site, concentration and variety of contaminants are less, and exposure is more limited to the volatile compounds and the inhalation route.

Determination of Actual Release

One of the important scoring factors in the current HRS is an on-off switch for the presence of actual release of hazardous material into the ambient air. The determination of actual release is usually based on a limited amount of air monitoring. The data provided by the program office indicate that 14.2% of the 951 NPL sites have shown observed release, compared to 41.6% for surface water and 73.0% for ground water. These statistics may be misleading and could result from differences in detection efficiency rather than true dominance of the water routes.

The differences in detection efficiency are also thought to result in a reluctance to collect data for this route, a problem which could be addressed by a minimum data requirement for the HRS.

Air releases are often intermittent, with a substantial temporal variation. Let "r" denote the fraction of days during which a release occurs at a site. If r>0, the site should be classified (in the current HRS) as having an actual release. Strictly speaking, both the release fraction and the presence of actual release are relative to the time frame under consideration. If longitudinal air monitoring is available for a long time period, and measurement error is negligible, the release would be observed. In the absence of longitudinal monitoring, there can be a substantial probability that a site with intermittent release would not show an observed release. If one assumes that air monitoring is conducted for one day, such as the day of site inspection (chosen randomly). For a site with release fraction,"r", (say 40%) the probability of not observing the release is 1-r, or 60%. Therefore, the prevalence of air release for the NPL sites can be substantially higher than the value of 14.2%, which is based on the available data on observed air releases. For example, if the release fraction for all NPL sites with actual release is 40%, the prevalence of air releases would be about 35% (14.2%/40%), among which only a small fraction is identified by the available data as showing an observed release. It is likely that air releases can be substantially more prevalent than what the available data indicate.

One possible remedy for the underestimation of actual releases is to increase the frequency of air monitoring. For a site with release fraction r = 40%, if air monitoring is conducted for three instead of one days, chosen randomly (because of possible intertemporal correlation, three consecutive days cannot be regarded as being random), the probability of not observing the release would be 21.6% instead of 60%. However, the amount of resources required to increase the air monitoring frequency would be substantial, and might not be cost effective.

As discussed above, alternative sampling methods such as soil gas monitoring may be easier than ambient air monitoring.

A2-11

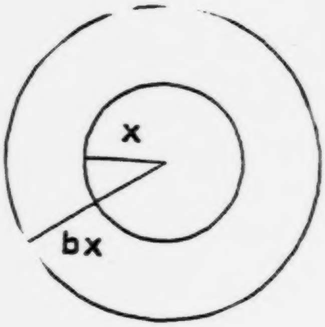
ATTACHMENT A

POINTS FOR SAB CONSIDERATION

- Use of a Single Target Distance Limit at all Sites
- Applicability of Air Emissions Information from TSDF to Superfund Sites
- Approach to assessing Health Risks (Is Cancer most Conservative?)
- Range of Emissions Estimates used

ATTACHMENT B

Derivation of the Air Target Score



Suppose population N is distributed uniformly in a ring between distance x and bx. The population density is given by

$$D = \frac{N}{\pi(bx)^2 - \pi x^2} = \frac{N}{(b^2-1)\pi x^2}$$

Suppose further that concentration, averaged over all directions, declines as an inverse power of distance:

$$C = k/r^n$$

If excess risk is proportional to concentration (as usually assumed for carcinogens), the proportionality constant is P, and excess risk=PC=P(k/r^n), then the population risk in the ring is given by

$$R_x = \int_x^{bx} (2\pi r\, dr)\left(D \frac{Pk}{r^n}\right)$$

$$= \frac{2\pi PkD}{(2-n)}\left[(bx)^{2-n} - x^{2-n}\right]$$

$$= \frac{2\pi Pk}{(2-n)}\,\frac{N}{(b^2-1)\pi x^2}\,(b^{2-n}-1)\,x^{2-n}$$

$$= \frac{2PkN\,(b^{2-n}-1)}{(2-n)\,(b^2-1)\,x^n}$$

Assuming the same population, N, the population in the next larger ring is given by

$$R_{bx} = \frac{2PkN\,(b^{2-n}-1)}{(2-n)\,(b^2-1)\,x^n b^n}$$

The ratio of the two risks is

$$R_{bx}/R_x = \frac{1}{b^n} \qquad \text{(this works for } n = 2 \text{ also)}$$

If we want this ratio to be 1/10, then

$$b^n = 10 \qquad \text{and} \qquad b = \sqrt[n]{10}$$

For example, if $n = 2$, $b = 3.16$. Note that if D is constant from ring to ring, the ratio of population risks is

$$R_{bx}/R_x = b^{2-n}$$

and will be greater than 1 if $n \leq 2$, implying that there is no "natural" limit for the air target distance.

Both atmospheric diffusion theory, available data, and current diffusion modeling practiced by EPA support a value for n of less than or equal to 2 for ground-level sources. At close-in distances, less than 10 km for example, the decay in the ring-averaged concentration is inversely proportional to the square of the radial distance from the source for average meteorological conditions. At distances greater than 10 km, the decay for average meteorological conditions is slower than quadratic. EPA models used in performing risk assessments, such as the Human Exposure Model (HEM), use formulas for diffusion that have the ring-averaged concentration decaying approximately as $r^{-1.7}$, for distances out to approximately 10 km for average meterological conditions.

As an example, one can refer to the table when a = 0.09 mile and b = 3.33 (n is about 1.9). Figure B-1 shows the rings for these assumptions and Table B-1 shows the matrix of scores.

TABLE B-1
Air Target Score for b = 3.33

Population	Ring Boundaries (miles)			
	0.09 - 0.3	0.3 - 1.0	1.0 - 3.3	3.3 - 11.1
$10^6 - 10^7$	10	9	8	7
$10^5 - 10^6$	9	8	7	6
$10^4 - 10^5$	8	7	6	5
$10^3 - 10^4$	7	6	5	4
$10^2 - 10^3$	6	5	4	3
$10^1 - 10^2$	5	4	3	2
$10^0 - 10^1$	4	3	2	1

(The scores above the line imply population densities greater than 30,000/mi^2, which are rare.)

If one assumes that population is uniformly distributed at density D = 1,000/mi^2, then the populations in the rings are about 260, 2900, 32,000, and 390,000 people. Each ring would score 6 points; the overall score would, therefore, also be 6.

The decline in individual risk per ring is by definition one order-of-magnitude. Therefore, if one arbitrarily defines risk to equal 10^{-3} for the innermost ring, then the corresponding population risk is 260 x 10^{-3} = 0.26 (less than one case in a lifetime). In ring 2 it is 2900 x 10^{-4} or 0.29, in ring 3 it is 0.32 and in ring 4 it is 0.39. Thus, total population risk continues to increase as long as the population density remains constant. Practically, individual risk has declined to 10^{-6} in ring 4 and would be negligible (10^{-7}) in a fifth ring.

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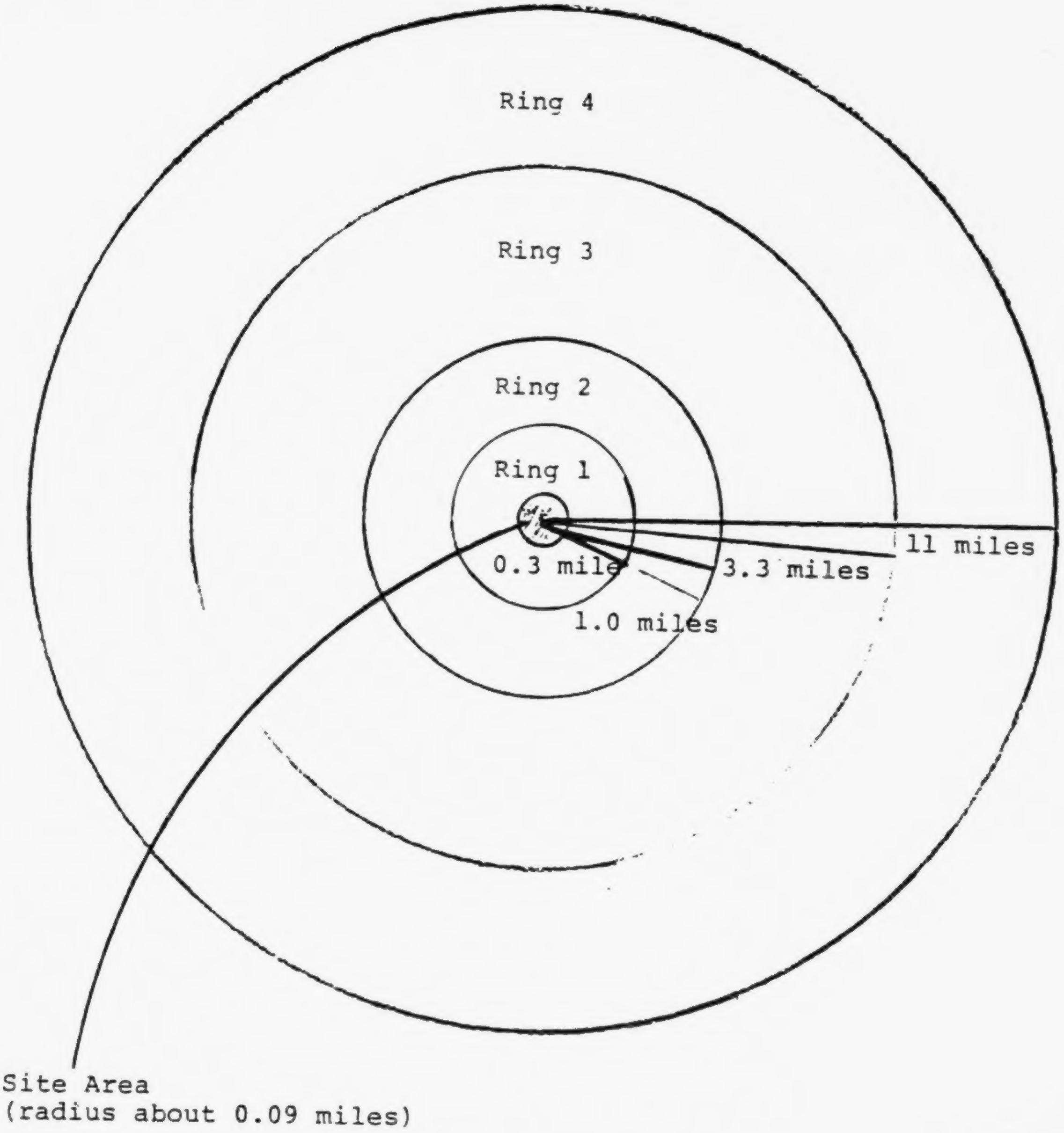
FIGURE B-1

Air Target Distance Score (not to scale)


Ring 4
Ring 3
Ring 2
Ring 1
0.3 mile
1.0 miles
3.3 miles
11 miles
Site Area
(radius about 0.09 miles)

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APPENDIX 3

REPORT OF
THE LARGE VOLUME WASTE WORK GROUP
TO THE
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
OF THE
SCIENCE ADVISORY BOARD

A2-16

U. S. ENVIRONMENTAL PROTECTION AGENCY
SCIENCE ADVISORY BOARD
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
LARGE VOLUME WASTE WORK GROUP

ROSTER

CHAIRMAN

Mr. Richard Conway, Corporate Development Fellow, Union Carbide Corporation, Post Office Box 8361 (770/342), South Charleston, West Virginia 25303

MEMBERS/CONSULTANTS

Dr. Keith Ferguson, Environmental Protection, Environment Canada, Kapilano 100, Park Royal, West Vancouver, British Columbia, CANADA V7T1A2

Dr. C. Daniel Kealy, U. S. Bureau of Mines, Spokane Research Center, East 315 Montgomery Avenue, Spokane, Washington 99207

Dr. James O. Leckie, Department of Civil Engineering, Stanford University, Stanford, California 94305-4020

Mr. Bruce Napier, Battelle NW, Post Office Box 999, Richland, Washington 99352

Dr. David Pollock, U.S. Geological Survey, National Center, Mail Stop 411, Reston, Virginia 22092

EXECUTIVE SECRETARY

Mrs. Kathleen W. Conway, Deputy Director, Science Advisory Board, (A-101F), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460

STAFF SECRETARY

Mrs. Dorothy M. Clark, Secretary, Science Advisory Board, (A-101F), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460

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ATTACHMENT A--Issues from The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites, July 22, 1987

ATTACHMENT B--Issues from The Superfund Hazard Ranking System (HRS): Feasibility of Using Concentration Data in a Revised HRS, July 27, 1987

BACKGROUND

Mr. Henry L. Longest, Director of the Office of Emergency and Remedial Response (OERR), referred the large volume waste issue, "whether large volume wastes should be considered differently from other wastes," to the Science Advisory Board for review in his June 25, 1987 memorandum (22). The issues as stated more specifically in the July 28, 1987 memorandum (20) of Mr. Stephen A. Lingle, Director of the Hazardous Site Evaluation Division (OERR) are:

"1) Applicability of the HRS in scoring mining waste sites; and

2) Feasibility of using waste concentration data in a revised HRS."

This memorandum also states, "we (OERR) believe that the Subcommittee findings will be equally applicable to both mining and fly ash sites." The Work Group concentrated on mining sites and assume OERR will translate its findings to utility waste sites.

The primary EPA document addressing the first issue, The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites (13) was reviewed at the Work Group's August 20, 1987 meeting. Besides providing background on the HRS, it presents an overview of mining waste site characteristics, summarizes five previous studies on the application of the HRS to mining waste sites, and provides an assessment of "potential dangers" at six such sites rated by the HRS.

In the overview of mining waste site characteristics, four major categories of wastes from the extraction of ores and minerals were addressed: mine waste, mill tailings, dump and heap leach waste, and mine water. (The Work Group had the Office of Solid Wastes' Management of Mining Wastes (17) and chapters 1-5 of the Draft Report to Congress: Wastes from the Combustion of Coal by Electric Utility Power Plants (16) as additional sources of information on the characteristics of large volume wastes). Metals, radionuclides, asbestos, and cyanides (but not organics) were identified as the contaminants of concern at large volume waste sites. The acidity (pH) was identified as a key factor in the mobility of metals, and the ground water and surface water pathways were those usually of concern at these sites.

Three of the five papers summarized and evaluated in the issue paper were prepared by TRC Environmental Consultants, Inc. for the American Mining Congress (27, 28, 29). The other two were Agency contractor reports developed by MITRE Corporation (24, 25) in response to issues raised by TRC. The TRC papers assert that the HRS does not adequately discriminate risks posed by various mining waste sites as well as it does for non-mining sites; the MITRE papers respond that TRC's conclusions are not supported by their analysis, or by further MITRE analysis.

OERR briefed the Work Group on its comparison of scores for six actual mining waste sites with the results of an assessment of the qualitative overall risk to human health and the environment (potential danger) at those sites (11). Ratings for four pathways were derived: ground water, surface water, air and direct contact. For these six study sites, higher HRS scores were associated with higher potential danger ratings.

In its July briefing of the Subcommittee, the Office of Policy, Planning, and Evaluation reported that its Site Ranking Panel (an in-house group of EPA personnel with varying degrees of expertised on Superfund issues), using a different group of sites and experts, apparently found virtually no correlation between the experts' ranking of sites and the HRS scores (18). Since the unpublished OPPE study (23) was not reviewed by the Subcommittee nor otherwise peer-reviewed, the Work Group is unable to judge what credence may be placed upon its findings. Taking the study at face value, it would appear that because most of the sites chosen were already on the NPL, this may indicate that the HRS discriminates poorly between listed sites, but does not necessarily mean the HRS does not discriminate between those that should be and should not be listed.

There are two ways to evaluate the applicability of the HRS to mining sites. The July 22, 1987 issue paper, The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites, uses the approach of evaluating the experience in ranking mining sites with the HRS system in terms of false positives and false negatives and differentiating according to the potential danger as determined by other means. In its evaluation, the Work Group coupled this approach with an examination of the scientific issues independent of the HRS experience.

The second issue paper is The Superfund Hazard Ranking System (HRS): Feasibility of Using Concentration Data in a Revised HRS, July 27, 1987. Besides providing general background on the HRS, the paper discusses the (non)use of waste concentration in the HRS, describes the use of waste concentration data in other site ranking models, and presents three options for using waste concentration in a revised HRS.

Basically, the inherent difficulties of sampling and analyzing hazardous wastes, the heterogeneity of waste sites, cost, and the need to quickly develop a NPL dissuaded the Agency from including concentration in the original HRS. Four systems which address concentration in various ways were described: the Site Ranking System (SRS), HARM II, Site Assessment System, and Remedial Action Priority System (RAPS). OERR viewed the SRS approach, a linear scoring system which falls just short of being a quantitative risk model, as having components of potential utility, but cautioned that any of the systems rely heavily on the professional judgement of field personnel.

The three options presented by the Agency for using waste concentration data in the revised HRS are:

W1 Retain the current HRS approach where waste concentration data are used only to identify the most toxic waste constituent.

W2 Mandate the use of waste concentration at all sites to determine a total mass of constituent to be used in the revised HRS, much as the waste quantity score is currently applied.

W3 Adopt a tiered approach to encourage the use of constituent concentration data, where available, and reliance on default values of concentration to estimate the total mass of a constituent at other sites.

The detailed questions posed to the Work Group on large volume waste issue are presented in Attachments A and B.

RESPONSES TO ISSUES/QUESTIONS RAISED BY OERR

Applicability of HRS to Mining Waste Sites

The full text of the questions posed by OERR can be found in Attachment A. An abbreviated form is used here to assist the reader.

Bias Against Mining Sites Not Demonstrated. The TRC and Mitre reports showed that mining waste sites scored higher in waste quantity compared to non-mining sites. This is expected given the large volume of wastes generated by the mining industry. TRC did not show this bias caused false-positives or false-negatives for mining sites. Both TRC and Mitre found waste quantity contributed relatively little to the final HRS score.

TRC addressed whether the degree of site information available was a major factor in NPL listing. Since some mining sites have more extensive data bases than do others, TRC concluded that these may be more likely to have higher scores and, therefore, to be placed on the NPL, compared with sites of equal risk but with less available information. Most major industrial facilities also will have more extensive data bases than smaller sites (especially "orphan chemical dumps"). Extensive data bases and a regulatory history may highlight major industrial sites before others. Moreover, more frequent and "denser" monitoring has a better chance to find environmental problems and observed releases; also, sites with serious problems may be more thoroughly studied. In any event, no data were presented by TRC showing that the relatively larger data bases for mining sites resulted in unfair scoring. On the contrary, smaller data bases could theoretically be biased. Use of default values for scores where data are missing would be a better solution to the alleged underscoring of sites with lesser data bases.

Analysis of the relative weights of components in the Hazard Ranking System may suggest bias if one kind of waste, such as mining wastes, always scores high in an important component irrespective of environmental hazard. TRC stated the final HRS score for mining sites could be predicted by population alone. Since the TRC studied only mining sites, it did not prove a bias against mining waste sites. Also, the more complete Mitre analysis indicated that population is the second-most important factor (after observed release) for scoring of all types of waste sites and, therefore, is a critical factor for all sites, not just mining sites.

In two areas, the Work Group concurs with TRC. First, inorganic metals have certain characteristics not addressed in a system that does not take into account differences in mobility between specific ionic forms. The Work Group assumes that OERR will consider these differences in the revisions to the toxicity/persistence score. Second, the large volume of mining wastes often means large masses of the contaminant are available for release, but certain conditions must exist for these releases to occur.

In summary, while the TRC analysis identified some important ranking priorities of the HRS system, its findings do not present a strong argument indicating a bias against mining sites.

Inadequacy of the HRS for Mining Site Evaluations Not Proven. After reviewing the TRC and MITRE studies as addressed in the July 22, 1987 issue paper The Superfund Hazard Ranking System: Applicability to Mining Waste Sites, the Work Group finds that the studies conducted regarding the HRS listing process are preliminary in that they have examined only small subsets of the data base, and are inconclusive. Therefore, sufficient experiential evidence has not accumulated and been presented to show an inadequacy of the HRS in regard to mining sites. The OPPE study (18) presentation at the July 16th Subcommittee meeting, "Preliminary Analysis of Alternative Models to Support Revisions of the CERCLA, Hazard Ranking System," also provided some data. That study involved mining sites and 16 nonmining sites and used a panel of in-house EPA personnel (with varying degrees of expertise in Superfund issues) to evaluate risk for comparison with the various existing ranking models. Within its limited study, OPPE found no consistency between its panel's ranking of risk and ratings from any of the models, including the HRS model. This data set for mining sites seems limited and cannot support a conclusion about the adequacy of the HRS scoring system.

In summary, sufficient evidence was not presented to the Work Group to conclude that the current HRS has been adequate or inadequate for mining sites (or even for non-mining sites).

Inappropriateness of the Existing HRS for Mining Sites Not Demonstrated, But Has That Potential. As stated above, the Work Group was unable to find sufficient evidence that the HRS has treated mining sites with systematic error. Further, although only a small subset of mining sites was available for analysis, the Work Group was unable to identify any sites currently listed that should not have been on the NPL. The present system has possibly rated mining sites no worse than other waste sites.

However, the present scoring system has a potential to treat mining wastes (and others) with systematic error. The vast majority of listed mining sites and, to a slightly lesser degree non-mining sites, have observed releases. Since TRC reported (25, page 9) that 95% of listed mining sites had an observed release and since observed releases require less judgement in scoring, there was a lower risk of false positives.

The Work Group believes the present HRS is not well suited for scoring potential releases from mining waste sites because mobility is not included, as discussed below.

Factors to Modify to Make the HRS for Large Volume Wastes. In regard to improving the HRS, the following points should be considered:

- Mine wastes (one of four types of mining wastes) tend to be solid rather than liquid, and contaminants may be less mobile.
- Where mining wastes contain low concentrations of hazardous substances in large waste volumes only partially isolated from the environment, environmental conditions instead of the extent of isolation may control contaminant release,
- Natural geochemical processes are often required to mobilize hazardous substances in mining wastes, such as acid generation by the biochemical oxidation of metal sulfides.
- The concentration of hazardous substances and the potential for release can often be estimated for mining wastes, i.e., acid mine drainage (AMD) potential and leaching tests. More generally, the HRS does not adequately consider the nature of the source, release, transport, and transformation.

Improved ways of considering the concentration, toxicity (inorganics have special characteristics), release (mobility in various matrices), and transport/transformation factors would make the HRS more accurate.

The concentration issue is addressed in the latter part of this report and Appendices 1 and 2 address the toxicity issue. OERR's briefing of the Work Group August 19-20, 1987 in Denver indicated that it is considering ways to incorporate mobility factors within the HRS that may have considerable promise (26).

Revisions of the HRS then under consideration by OERR included substituting a mobility factor for the persistence factor in the ground water and surface water pathways. In the ground water pathway parameters representative of the tendency for contaminant mobility and the sorptive capacity of the geologic media would replace the persistence parameter. The Work Group supports such changes because mobility is a more discriminating concept for both inorganics and organics than is persistence in the subsurface, especially with respect to inorganic compounds.

The Work Group recommends that, during the development of a structured value representation of the mobility concept, OERR should explore a means of incorporating important matrix characteristics. These include extreme pH, any crystalline phase modifications of mining wastes that differ from native geologic materials, and the sorptive capacity of surrounding geologic materials (influencing migration tendency).

Extreme pH is a particularly attractive characteristic because it is meaningful and because the pH of mining wastes can be determined relatively simply and accurately. Mining wastes tend to be highly buffered, either acid or alkaline. All fluids on a mining sites could be tested for pH and solids could be tested for paste pH, particularly near the surface (30). The pH of pathway media and receiving waters are more difficult to determine accurately. However, even here, samples should be obtained and measured for pH in both the field and the laboratory.

In regard to the surface water route, OERR favors retaining persistence as the parameter to couple with toxicity in the waste characteristics portion of the HRS, but would consider four additional transformation processes along with the current biodegradation one. The Work Group concludes that inclusion of these additional factors would improve the existing HRS because it more closely corresponds with what happens in the real world.

Mobility would be included in the air route; a gas mobility factor value and a particulate mobility factor value would be combined. Details were unavailable, but the basic approach of including mobility should be pursued due to its importance along with waste quantity in the exposure potential scenario. (See also Appendix 2 on exposures through the air.)

Feasibility of Using Concentration Data in a Revised HRS

The full text of the questions posed to the Subcommittee by OERR can be found in Attachment B. Abbreviated versions are used below.

Value of Incorporating a Concentration Factor. The following discussion assumes that the structured value model construct of HRS will be maintained in the short-term.

Modifying the current HRS to incorporate factors which capture some measure of both the physical-chemical characteristics of the hazardous constituents and the nature of the waste matrix, as well as those site characteristics responsible for risk, is clearly an improvement. Modifications relating to the form and concentration of the hazardous constituents (HC) would add a degree of sensitivity to the HRS and possibly capture some measure of mobility and potential for exposure. Possible factors include HC concentration in the waste material, total mass of the HC, potential for release of the HC, mobility of the HC in the ground water, and concentration of the HC in the ground water.

It appears that the most useful way to implement a modification of the HRS to facilitate inclusion of additional factors, as well as create flexibility to accommodate a range of site data quality and quantity, is to augment the HRS with a multi-tiered default approach for use of HC concentration or quantity data. Such a multi-tiered structure would provide alternative routes for use of data differing in quality and quantity, as well as provide the opportunity for inclusion of a decision point on the question of acquiring new, additional data for the HRS scoring process.

Perhaps the concept of using the most appropriate tier for a specific situation is more important than assuming that the top tier is best, and only defaulting to a lower tier. That is, for solid and semi-solid wastes at mining sites total quantity of hazardous waste makes little sense in the absence of mobility factors; rather, the concentration of the contaminants is important. For drum and other liquid wastes, the total quantity of hazardous material is probably important.

Desirablity of Including Hazardous Constituent Concentration Data in the HRS. Because both the impact of observed releases and the risk of potential releases are related to source concentration, particularly for the direct contact and air pathway, including hazardous constituent concentration in the HRS would be desirable.

At present, the HRS is only a screening tool used by OERR, in combination with other science policy considerations for deciding if detailed (RI/FS) studies are required. SARA encourages the development of a more accurate and comprehensive ranking system. Addition of concentration data could improve the accuracy of the HRS.

EPA has proposed two options (W2 and W3) for modifying the HRS to account for the concentration of hazardous constituents. Both approaches translate waste constituent concentration data into an estimate of the total mass of a hazardous constituent at the site, which is then used to compute the waste quantity score for the HRS. Both approaches represent improvements over the current HRS. However, if mobility is not addressed, even the approach which uses "total mass" of hazardous constituent could contribute to produce false positives for some large volume wastes and some pathways.

For the ground water pathway, the concentration of a constituent in a solid waste is of much less importance than the concentration that constituent may attain in the leachate migrating away from a site. Consequently, more emphasis should be placed on the partitioning of hazardous constituents between the solid waste and the leachate. Leachate concentration (at least estimated) should then be factored into the HRS waste quantity term. For wastes that are not in solid form, total contaminant mass quantity should continue to be used.

Options for Incorporating Concentration Data In the HRS. Option W2 would require that waste constituent concentration data be collected at a site before it could be scored. In contrast, Option W3 (the Work Group's preferred approach) is a tiered system that would encourage the use of concentration data, but would also provide the flexibility to use indirect estimates, or default concentrations, to estimate a constituent's total mass when direct measurements of concentrations are not available. The direct measurement approach of option W2, modified for solid wastes to account for partitioning between water and solid, would provide the soundest scientific basis for the revised HRS. In most cases, however, it will not be practical due to safety and cost considerations to require waste constituent concentration data for every site at the site inspection stage. Furthermore, the Work Group recommends the direct use of concentration rather than conversion to a mass value for wastes in solid or semi-solid form.

One of the most difficult tasks will be to decide which tier to use. In the case of option W3, there is a need to decide whether to use measured concentrations or indirect estimates of mass. It is likely that economic and safety considerations will determine the decision as to which tier will be used. If a site is relatively uniform and sufficient waste constituent data can be obtained at reasonable cost to characterize the waste, tier one (concentration) could be used. On the other hand, if a site is non-uniform and costs of obtaining the necessary concentration data (or time and safety requirements) are prohibitive, it would be reasonable to use a higher tier. In effect, this approach may effectively distinguish between inorganic (mining and utility) and organic waste sites because of the greater heterogeneity of organic waste sites and the large expense of organic analyses. Inorganic analyses are relatively inexpensive (assuming speciation is calculated, not measured); therefore, this approach would encourage the collection of waste constituent concentration data at mining sites, where concentration data is often a critically important factor, as discussed above.

In conjunction with using concentration data in the HRS, a method of determining a "representative concentration" for a site based on a stratified sampling strategy would be useful. In this approach, a complex site could be subdivided into a set of more homogeneous regions or strata, and a representative value for each stratum determined through more limited sampling. Statistical techniques exist for manipulating stratified data, which could then be recombined with appropriate weighting into a final single HRS score for the site.

To define a factor for converting quantity of hazardous constituents to quantity of hazardous waste, from a scientific point of view, the median concentration obtained in the September 1986 MITRE report by Arlene R. Wusterbarth, Hazard Ranking System Issue Analysis: Relationship Between Waste Quantity and Hazardous Constituent Quantity (32) should be used. OERR reported orally that this median concentration of all HCs at all sites is 450 mg/kg, but there was wide variation. This value relates to aggregates of constituents and only materials on certain lists of hazardous constituents were sought. Hence, risk management or policy considerations might cause EPA to select another value for the default concentration. One alternative is to convert HC to toxicity units (concentration times a relative toxicity factor) rather than concentration.

A specific rule for moving between levels (tiers) in option W3 might be considered. The first level (total amount or concentration of hazardous constituent) should be used where data are sufficient to support an estimate of hazardous waste constituent quantity. This would occur where there are data to determine the hazardous waste quantity accurately. What data are available clearly show the quantity is significantly above the amount necessary to receive the maximum score, or significantly below the amount necessary for the next-to-minimum score.

Where the quantity of hazardous constituent(s) is not known, scores could be calculated using the procedures of each of the first three levels. Then, scores for level 1 and level 2 would be compared. If the scores were within 25% of one another, the score for level 1 would be used. If the scores were greater than 25% apart, the score from level 2 would be compared to that from level 3. If level 2 and level 3 scores were within 25% of one another, then the level 2 score would be used; if not, the level 3 score would be used in the HRS. The final level 4 score would be used where data on waste quantity were virtually absent (especially for well fields).

Other Comments on Concentration. The Work Group commented on five additional issues related to the use of concentration data in the HRS.

1. Some Technical and Practical Considerations. OERR's issue paper on the feasibility of using concentration (14) addresses only waste concentration data. The Work Group recommends that concentration in the receiving environment, and perhaps population densities, also be considered as discussed in the Wolfinger report (31). Data on receiving water concentration data would aid in scoring observed releases. Fish bioassay data may be useful at times in ranking toxicity of releases in the absence of, or in addition to, chemical concentration data.

Sites will have data bases of differing completeness and accuracy, as occurs now in site evaluation. Modified scoring systems must use large data bases effectively to produce more accurate scores while handling with equal fairness sites with fewer data.

Some toxic contaminants, such as metals, can be measured in both solids and liquids at reasonable cost. All site inspections at mining sites could gather valuable data on the quantity of metals in the liquid and solid phases of the waste.

2. Evaluation Techniques. The revised HRS should be tested for both high strength concentration/low volume wastes (drums) and low strength concentration/high volume wastes (mine tailings), with both observed releases and potential releases of contaminants.

   The sensitivity of the new ranking system to concentration should be tested to determine the importance of concentration in listing on the NPL and, thus, the need to obtain more complete and accurate hazardous waste consititue‌nt data. The analysis would also be a first step in examining possible false positives and false negatives.

3. W2/W3 Modification. A non-linear scale such as that currently used for waste quantity may be appropriate. Such a scale would give low scores to small, less significant sites, while not unduly penalizing large sites. In a properly constructed algorithm, sites which are less significant in terms of risk will score lower than those sites which present greater risks.

   For unknown waste quantities, the default scheme suggested by Kushner in Hazard Ranking System Issue Analysis: Sites with Unknown Waste Quantity (19) is prefered over a minimum default value.

4. Quality of Waste Concentration Data. Sampling guidelines could be developed for each waste type (i.e. drums, tanks, tailings, impoundments, etc.). These could be modified by site inspection staff based upon site specific factors, but a minimum sampling scheme should be identified.

   Perhaps a relatively large number of samples could be collected, but only a limited number analyzed initially. The initial results and calculated HRS scores could be used to decide on the need for additional analyses. This approach would apply only to contaminants that could be preserved.

More data may be required for sites with no observed release because they are more likely to score below the 28.5 boundary, and waste concentration data are critical in assessing the risk of potential releases.

Composite samples should be obtained to reduce the number of analyses, while providing estimates of average waste concentration.

5. Sampling Risk. Waste sampling schemes should be developed based on a thorough review of existing data on hazards to sampling personnel. Description of the waste, anecdotal evidence, and data on the receiving environment should indicate the hazards posed to site investigators. In suspected high-risk sites, the sampling scheme should begin around the perimeter where less contamination is expected, and progress towards the areas of expected higher concentrations (this is also consistent with good sampling technique). Small test holes and gas sampling equipment could be used on the actual site to test for hazardous conditions.

   Data requirements could be relaxed where severe onsite health and safety hazards exist. In any case, these sites should probably be addressed by the Superfund Removal Program for their direct contact, fire and explosion capabilities.

OTHER COMMENTS

Long-Term Considerations

Although SARA mandates a re-evaluation of the HRS, and presumably a revision or alteration in a compressed time frame, it is nevertheless useful to consider both the long-term and short-term requirements of the HRS and subsequent site evaluation process. In that context, these remarks focus on the issues involved in development of quantitative representation of concepts involving contaminant concentration in the waste materials, contaminant concentration in ground water and mobility (a notion that combines release and transport).

Clear qualitative differences exist between many large volume waste (LVW) sites and the more numerous hazardous waste sites containing admixed synthetic organic/inorganic hazardous constituents in both liquid and solid form. LVW may be segregated into monofills of a single waste type. Some sites have multiple types of wastes (e.g., mill tailings, smelting slags). Where these wastes are spatially separate, the sites may be relatively easy to characterize. Commonly, LVW sites contain low concentrations of hazardous trace elements (HTE) in the waste matrix.

The release of these HTE is governed by very specific geochemical processes and is subject to migration constraints. Scientists and regulators increasingly understand the effects of these two factors on release.

Long-term evolution of the HRS should include consideration of detailed numerical geochemical transport/fate models currently under development. The advantage of eventually using transport/fate models in the HRS is the explicit inclusion of quantitative representation of specific processes and mechanisms responsible for the release, transport, transformation, and retention of hazardous compounds. The use of these models entails with enlarged data requirements, but can yield less ambiguous, more detailed simulations appropriate for pathway calculations and, ultimately, exposure estimates. Considerable time and effort will be required to integrate these more complex transport/fate models into the overall framework of the HRS and to test their performance.

Need for Additional Studies

The studies of large volume waste presented to the Work Group contained little in the way of original investigation. Looking to future improvements in the HRS, OERR should plan thoroughly peer reviewed studies, both to review large volume waste sites ranked under the HRS and to examine basic parameters in the model. A study of the first type was suggested by Mr. R. Walline of EPA Region VIII which could address the actual reasons why release occurred at problem mining sites (reasons reportedly are different than those initially assumed). A study of the second type might address the characteristic(s) of mining waste that control release (mobility) to ground water.

Search for False Negatives and False Positives

Because it is difficult to design a system that can in all cases make the best use of all the site-specific scientific information available, the Agency should consider the advantages of utilizing additional scientific judgment outside of (or adjunct to) the HRS model in making decisions on whether to list sites on the NPL.

Screening models like the HRS must be simple. They do not have much resolving power and therefore, some false positives and false negatives are inevitable. Because of this limitation, HRS scores should not be overemphasized. A process should be established either to review sites subject to scoring or to review HRS scores in an attempt to spot false positives and negatives. Such a scientific review process could involve the use of additional models; in many cases, however, obvious false negatives or positives might be best handled by a "manual" review. The important point is that the system be flexible enough to allow for a variety of approaches to be used, as needed, during the scientific review process.

The extent of waste characterization data to be collected at the SI level is part of a cost/benefit calculation. The economic impact of being falsely included or not included on the NPL should be considered.

SUMMARY

Studies of the experience of applying the HRS to mining sites have not proved systematic error unique to such sites.

However, the HRS has a potential to produce abnormally high scores for mining sites due to the manner in which toxicity, mass, release, and transport/transformation processes are addressed.

A3-14

ATTACHMENT A

The Superfund Hazard Ranking System (HRS): Applicability to Mining Waste Sites, July 22, 1987, defines the issues for SAB consideration as follows:

1. "Does the series of TRC analyses indicate that the HRS is unfairly biased against mining waste sites (as compared to other types of potential Superfund sites)?
2. "Is there sufficient evidence that the existing HRS scoring/NPL listing process has been inadequate with regard to mining sites evaluated to date (i.e., produced numerous false positives or false negatives)?
3. "Has it been demonstrated that the existing HRS is an inappropriate scoring system for determining whether mining waste sites should be listed on the NPL (i.e., subjected to further investigations and analysis)? If so, what factors should EPA consider modifying to make the current HRS more appropriate for mining sites?"

ATTACHMENT B

The Superfund Hazard Ranking System (HRS): Feasibility of Using Concentration Data in a Revised HRS, July 27, 1987 defines the issues for SAB consideration as follows:

1. "Based on the information presented and other data available, does it appear to be desireable to include waste concentration data in the HRS?

2. "What additional technical and practical considerations ought to be factored into the decision as to whether or not waste concentration data should be included in the HRS?

3. "Can the SAB suggest any systematic quantitative or semi-quantitative methodology for deciding whether to include waste concentration data and for evaluating systems that do so in the HRS that would consider effectiveness of the system at generating risk-based scores, the costs of data development, and potential improvements in decision making?

4. "Which of the suggested new approachs (W2 or W3) appears to be more desireable?

5. "Can the SAB suggest any changes in the structure of options W2 or W3 that would make them more desireable (e.g., changes in decision rules, parameter values)?

6. "What quality level of data on waste concentrations data quality (what types, amounts, and level of precision) should be required if such information is to be used in developing HRS scores? Is there a simple, robust way to specify data quality that could be easily applied by a wide range of field personnel at a wide variety of sites?

7. "With regard to alternative W3: --What general advice can be given regarding how to define rules for moving between tiers? How ´good´ does waste concentration data need to be to allow its use?

   --Does the approach taken to defining conversion factors (particularly the assumption of 200 ppm typical waste concentration) appear to be reasonable? What alternatives could be suggested?

8. "What approaches can be taken to mitigating risks to field personnel during waste sampling? Should data requirements be relaxed at sites where severe on-site health and safety hazards exist?"

APPENDIX 4

COMMENTS ON EXPOSURE
BY THE
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
OF THE
SCIENCE ADVISORY BOARD

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EXPOSURE

Why is it Important to Address Actual and Potential Exposure

Exposure occurs when there is contact between pollutants and receptors. Addressing exposure is important when there are toxic chemicals present because the determination of whether there is any actual or potential risk to health or the environment depends on both exposure and toxicity Where there are no toxic substances or where there is no exposure to them, there is no risk. To the extent that the HRS is intended to assess relative risk, it must address both toxicity and exposure sufficiently to determine risk. Where information on either toxicity or exposure is incomplete, risk cannot be fully assessed. Risk can be evaluated by assessing four factors: (a) the presence of chemicals, (b) their toxicity, (c) their potential for release and mobility, and (d) the probability of human and environmental contact.

Options for Assessing Exposure

Ideally, a quantitative risk ranking system would rely on data for all variables of the risk algorithm. Because it is not possible to obtain quantitative data for all the necessary variables, semi-quantitative approaches must be considered. Surrogates for quantitative values may be developed through several means. They include identifying the appropriate measure of central tendency for the known data values, modeling values from the few known data points for the site of concern or for comparable sites, using indirect measures (such as total waste volume as a substitute for concentration), or simply applying points in the algorithm based on a subjective evaluation of the available descriptive information for the site. An example of a tiered approach for the use of waste quantity information is discussed in Appendix 3. A similar strategy could be developed which uses measured values in preference to indirect estimates for a variable of exposure. When the ideal data are not available, however, options to estimate the parameter can be used in a tiered process that moves away from actual measures toward increasingly indirect measures. In this manner, the maximum value of the data is retained while the goal of evaluating a variable is met.

Exposure should be assessed in a manner that is both chemical-specific and pathway-specific as noted in Appendix 2. The potential for release and mobility is related not only to the chemical of concern but also to the environmental media through which it must travel before exposure can occur. Without this specificity, any attempt to address exposure is likely to result in inaccurate estimates of risk.

The most attractive option is to determine the presence of individual chemicals of known toxicity and then assess their potential for release, mobility, and contact with humans and environmental receptors. Much could be gained by adding a chemical-specific exposure score that could be combined with chemical-specific toxicity scores to determine which chemicals dominate the risk at a single site and how the risk might compare across sites that are otherwise similar (e.g. in population distribution, existence of valued environmental resources, hydrogeology, meteorology, and containment). While little is known about the amounts of chemicals present and their concentrations in environmental media after only a site inspection, the insights to be gained from a chemical- and site-specific approach are so great that it should not be lightly dismissed.

Relationship of Source Characteristics to Emissions

The HRS has been limited by not taking into account the potential for mobility of specific chemicals through specific pathways. Clearly, detailed estimates of pollutant emissions by pathway are not feasible with the information and resources available for scoring a typical candidate site with the HRS. (Here emissions should be taken to mean pollutant discharges generally, not just those to the air.) Given some minimal information about a site and its chemical inventory, however, it may be possible to make crude estimates of partitioning among environmental media and, therefore, of emissions by route which could be used to generate part of a chemical-specific exposure score.

Information needed to derive such estimates includes:

1. An estimate of the total mass or source concentration of important chemicals at the site.
2. A description of the site-specific factors influencing release, e.g.; impoundment vs. landfill.
3. Partition factors applicable to the chemical, e.g., Henry's law constant and organic carbon partition coefficient.

Some characterization of the potential for migration also allows better consideration of time as a factor in site management. A chemical that quickly moves off-site through air or surface water may pose high risks to surrounding populations in the short-term, especially if it acts as a threshold toxicant, whereas an immobile (but persistent) chemical will remain a potential hazard for long periods, especially if it is a non-threshold toxicant, e.g., a carcinogen. Estimates of the total mass deposited and the emission rates would permit an estimate of the site's "lifetime" if not remediated. Such estimates might provide a better appreciation of the urgency for remedial actions.

How Comprehensive Should the HRS Be in Addressing Environmental Pathways and Routes of Exposure?

Both toxicity and potential for exposure depend on environmental and biologic processes. An evaluation of environmental pathways addresses the environmental parameters that affect risk and an assessment of routes of entry provides the information needed to estimate risk to humans and and the environment.

Environmental Pathways. Environmental pathways include air, water (both ground and surface waters), soil and intermediate compartments such as plants and animals that become part of the human food chain. The potential for release and mobility of chemicals through these pathways affects risk estimates. Factors to consider include vapor pressure, time of transport from point of origin to populations at risk, chemical transformations that may occur during that time, and the toxicity of the chemicals that are expected at the point of exposure. Chemicals behave differently in different environmental pathways, so all pathways need to be evaluated fully to estimate risk.

Routes of Exposure. Routes of exposure (entry) occur by ingestion (through water, food and soil), inhalation (through air and water vapors), and direct contact (through water and soil). Biological processes such as metabolism and pharmacokinetics affect the dose delivered to tissues that may experience adverse effects. Biological uptake, delivery to tissues and transformation of chemicals to more toxic chemicals within the body are aspects of risk that can not be directly assessed in the HRS. As a result, where route-specific toxicity information exists, the toxicity and biological impact of chemicals need to be estimated by route of entry and incorporated into the toxicity factor of the algorithm. Without a syntheses of these route-specific evaluations, risk may be either incorrectly estimated or under-estimated.

MEI and Population Risks. SARA Section 105(a)(8)(A) states that the HRS should take into account "the population at risk." The Maximally Exposed Individual (MEI) is not considered in CERCLA or SARA. While population risks always come into play due to the impact of collective individual risks, some "minimal" individual risks (such as birth defects) associated with the MEI approach have major lifelong impact. Furthermore, the MEI is a very widely used measure of risk.

The current HRS addresses MEI in considering distance to nearest well and population risks in considering air target distance.

How can the revised HRS better account for exposure, both actual and potential?

Exposure requires contact between person and pollutant with risk focused on this point of contact. Sources; transport and fate; and the presence, nature,and activities of receptors are relevant to exposure.

Measurement of exposure may be person-based or community-based.

The current HRS finesses the assessment of exposure and instead uses the probability of release (and other factors such as persistence, waste quantity, distance to nearest well and population affected) as proxies for exposure.

The main difficulty of accounting for direct exposure stems from the need to consider potential as well as actual exposure. There are two aspects of exposure to be considered here--the concentration of contaminents in the environment around the site and the number of people around the site. Actual release may be demonstrated by environmental sampling. Potential release may be addressed by considering properties of the site and chemicals present such as distance to ground water and volatility. Similarly, the number of people (receptors) present and actually exposed today can be counted, while the number of people potentially present at the location in the future can only be estimated from studies of population dynamics.

While estimates of person-based exposures can be developed from biological samples, from personal household samples, from self-reported exposures, and from self reported symptoms, each approach has its limitations. As a practical matter, biological samples are rarely available. The cost of personal or household samples are prohibitive and would allow only limited opportunities to evaluate potential ambient exposures. Because subjectivity can easily enter into self-reported exposures, objective measurements need to be used to limit the subjective variability. Subjectivity also enters into reports of symptoms (whether self-reported or based on medical record studies) which serve as a proxy for exposure. Nevertheless, the reporting (by nearby residents) of physical symptoms consistent with acute effects of contamination from the site could be considered as evidence of possible, but not confirmed releases. This is one of the situations which could be addressed by the assignment of discretionary points to the HRS score. (see Appendix 5)

Community-based exposures can be developed from ambient pathway measurements, from site measurements, or from modeled exposures. Numerous assumptions about targets (such as animals or humans) and their behavior are needed to impute exposure from ambient pathway measurements. However, even more assumptions are needed to impute exposure from site measurements (see also source characterization discussion above) because the monitors are placed further from the potentially exposed population requiring additional assumptions about the time and mobility factors that operate between the source and target population. Even more assumptions are required to model exposure from similar sites because no two sites are exactly the same. Modeled exposures may be based on similar sites and can be used to predict rare events. The latter two approaches (site measurements and modeling) are discussed further below.

The way the current HRS addresses source characterization--including both the evaluation of the mobility and fate of chemicals and the consideration of concentration or quantity of chemicals--is insufficient to model exposure.

Incorporating concentration and mobility could produce a more comprehensive ranking scheme. One way to do this is by using concentration as a weighting factor for the waste quantity. The resulting effective waste quantities for low quantities of high-concentration waste might be similar to those for large quantities of low concentration wastes. Similarly, the scores for toxicity/persistence and for effective waste quantity could be adjusted by considerations of mobility.

From a scientific standpoint, exposure may be modeled by imputing an exposure for a site based on what is known of similar but more fully studied sites. If there are sufficient data on the actual exposures from sites with similar characteristics a potential exposure for the specific site could be imputed, but it is more difficult to define sites which are comparable in this context than to define sites which are comparable in terms of quantity and concentration. For exposure, the sites have to be comparable in geology (especially in mineralogy) as well.

A4-6

APPENDIX 5

COMMENTS ON THE ALGORITHM
BY THE
HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE
OF THE
SCIENCE ADVISORY BOARD

A4-1

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ALGORITHM

Background

The Hazard Ranking System operates through the following three steps:

1. To the extent possible, specified information regarding the properties of the site and of the chemicals deposited there is gathered and described quantitatively or qualitatively according to the needs of the HRS.

2. The information is manipulated, usually through comparison to categories in tables provided in the HRS manual, to yield a series of factor scores. The specifications of the conversion from raw information to factor scores may be called scoring rules.

3. The individual factor scores are combined within categories and then the category scores are further combined to yield route scores and eventually an overall migration score for the site. The specifications of how the scores are to be combined may be called combining rules.

Together the scoring rules and the combining rules form the overall logic and procedure, or algorithm, for the operation of the HRS. To a substantial extent, the methods for gathering the raw data (step 1 above) and deciding how much effort should be expended on that step are left to the individuals doing the scoring. The algorithm, however, is a fixed procedure that undergoes OERR sponsored quality control. As such, it is the key to how well the HRS will perform in assessing relative risk. Both the relationship of the raw data to the factor scores and the ways in which the factor scores are combined must be treated carefully and consistently to optimize the performance of the HRS.

Why is it important to pay attention to the overall algorithm?

Improving the algorithm could potentially do more to improve the HRS than fine-tuning individual components.

The algorithm should be approached by thinking about the best way to assess risks for a hazardous waste site without regard to the availability of site-specific information and then simplifying the rules (but not the logic) as needed to take into account real-world constraints --that is, to identify the most important variables and then develop data (or surrogates) and combining rules.

The overall algorithm needs to meet the intended purposes of the HRS as stated by SARA. SARA requires EPA to modify the HRS so that, "to the maximum extent feasible, it accurately assess the relative degree of risk to human health and the environment posed by sites and facilities under review." In Mr. Longest's June 15, 1987 memorandum (see Appendix 7 for full text) he states, "OERR believes that the purpose of the HRS is primarily a screening tool used to determine which sites will be candidates for Fund-financed remedial response. To the degree possible, the model also needs to provide a stratification of sites based on the relative risks posed to human health and the environment." It is not clear that the current system stratifies by risk, nor that it can serve as a successful on-off screen without stratifying by risk at least in the region of the cut-off score.

At a minimum the HRS must discriminate sites into two risk groups--on or off the NPL. Ideally, the HRS would individually rank all sites based on accurate ascertainments of risk--resulting in as many relative risk ranks as there are sites to be ranked. While the binary ranking is minimally sufficient, it is apparent that programmatic concerns demand a ranking that is more than binary. The decision about the level of ranking was not within the scope of the Subcommittee's review, instead the Subcommittee focused on developing conclusions and recommendations for the scientific bases of an effective ranking system. The Subcommittee proceeded to evaluate the various components and structure of the algorithm to work toward a scientifically valid approach to estimating risk.

One such component relating to risk is the toxicity score. The additive structure of the matrix weights the lower end of the two components (toxicity and persistence) and thus implies that any toxic effect or persistence is more important than the probability or severity of the effect or the degree of persistence. These baseline assumptions have the effect of treating toxicity and persistence in a binary manner, but this method of assessment may not be sufficient to meet the goals of the HRS and the Subcommittee did not find it to be an acceptable approach if the HRS outcome is expected to be more than binary. In addition--and as evidenced by the very high percentages of sites receiving the maximum score for toxicity and persistence--the inability of the current toxicity module to rank substances effectively on relative risk puts a severe limitation on the entire HRS to discriminate between sites on the NPL and thereby to prioritize appropriately on the bases of public health and environmental protection concerns. The scoring methodology needs to be re-evaluated in terms of the overall purposes of the HRS.

Can the revised HRS represent relative risk? Or can it only serve as an "on-off" switch? What do these choices mean?

The Subcommittee has suggested changes that will allow the HRS to provide a more accurate and scientifically based estimate of the relative risk of candidate sites. To the extent possible, the HRS scores should correspond to an objective evaluation of relative risk at sites. However, this is not always feasible due to both scientific and data limitations, as well as the value and policy decisions implicit when considering and balancing human health and environmental impacts.

While recognizing that the Agency must continue to base NPL listing decisions on many factors in addition to the HRS, the Subcommittee believes that a revised HRS, better designed to evaluate sites by relative risk, will provide an improved mechanism for determining which sites should be included on the NPL, and can potentially provide meaningful input to the subsequent assessment of NPL sites. Most of the changes needed to revise the HRS are changes in the overall algorithm and not changes with vast new data requirements. (Pages A5-5 through A5-8 discuss desirable changes in the algorithm.)

If the HRS is to be used to set priorities based on relative degree of risk, many factors need to be considered systematically in setting priorities.

Although it is possible to talk about an on-off switch and evaluate the HRS by whether it rates most sites on when they should be "on" and vice-versa, in fact there is a continuous range of scores with an arbitrary cut-off level designed simply to get 400+ sites on the original list. Unless the list is in reasonably good order both above and below the cutoff, its fidelity in distinguishing high and lesser risk sites will depend markedly on the choice of the cutoff, i.e., on how many sites (or what percent of sites) are wanted on the list.

There are costs associated with misclassification. If the HRS will be used to decide whether or not to spend $850,000 on an RI/FS, the economic cost of a false positive is approximately $850,000 to the fund (although less to society because even the low-risk site might need remediation and would benefit from the RI/FS). The social cost of a false positive may be reflected in decreased property values, increased physical stress and community concern, and in extensive time and effort expended by public and private officials attempting to address these concerns. The social cost of a false negative is the difference in average risk between the sites that should be on and those that should not, less any benefit of attention independent of Superfund. Unfortunately, the average risk of Superfund sites is not known, let alone the risk of those that were scored but which did not make the NPL.

The difficulty remains that there has been no analysis to determine whether the current HRS score is a good predictor of the risk ultimately generated by the formal risk assessment process conducted during the RI/FS phase. This evaluation needs to be done as a guide to future modifications of the HRS.

The question remains, "risk of what and to whom?" To create a risk-based HRS that evaluates sites, EPA would first need to reach an acceptable definition of risk which combines the health, ecological, and economic damages expected over the life of the facility. The Subcommittee favor multiple measures including a human population risk measure. The latter is especially important because quantitative techniques are available to assess it. Some subjective increases or decreases in score could be used to account for severity of human health effects and likelihood of effects on non-human biota.

What methods are available to develop a ranked list?

There are three common methods for developing ranked lists.

One way is to devise a highly simplified mathematical model that produces a number that is approximately proportional to the true ranking variable--in this case, some agreed-upon definition of risk. (Actually, all that is required is that the number increase monotonically with risk.) The system referred to as "RAPS" is such a model. Although simplified modeling has the advantage of being related to risk, it has the disadvantage of being a very substantial departure from the current HRS. RAPS is probably too complex to work well with the limited data available for most HRS candidate sites, even though it has worked well for DOE sites.

Another method is to devise a series of screens that successively divide the list of all sites into categories, which are later ordered in some fashion that is approximately the same order as risk.

The third major technique, often simply referred to as "scoring", is structured value analysis, of which the current HRS is an example. Although the other two approaches have their virtues, it is reasonable to concentrate on variations of the structured value approach because the current HRS uses it. Even here, two different approaches are possible.

The current HRS appears to take a so-called "empirical" approach. That is, a superficially plausible set of rules was developed and then modified "empirically" to match a subjectively ranked test set of sites. If the subjective ranking was truly what the HRS was supposed to achieve, and if the test set was adequately representative of all sites to be scored, then this method is perfectly satisfactory.

The other approach, a risk assessment approach, is to begin with a clear understanding of how to rank the list quantitatively if all the needed information and resources to process it were available. Then the risk assessment is simplified until it is obvious how to transform it into a scoring system. The scoring system is further simplified until it can operate at a reasonable cost on the often very sparse information available. For example, the population risk at a site might be represented by the sum over all routes of risk by route, and each route-specific risk might be represented by the sum of all chemical-specific risks by route. Each chemical-specific risk might be represented by an integral over population at risk of the product of toxic potency and time integrated exposure.

What rules should be used to develop scores based on risk?

First of all, internal consistency is important. Making rules that are consistent requires little up-front investment and no additional costs in the scoring of specific sites. These changes may be much more cost-effective than additional data collection.

The way that the various pieces/components of the score compile should reflect how their real world counterparts interrelate. The approach for accomplishing this is to begin with a physically-based exposure assessment model for each exposure pathway, structured properly to translate expected or potential releases into environmental concentrations and subsequent exposures and effects. These models would, of necessity, be highly simplified for a screening assessment. Even a simplified exposure assessment model may not be feasible given the time, resource and data limitations associated with the HRS process. Still, the manner in which the pathway scores are estimated and combined should be consistent with the fundamental material balance and exposure principles of such an underlying model. The following points discuss how this can be accomplished in the context of the structured value approach used in the current HRS system.

In a scoring system designed to reflect relative risk, the scores could be added across routes and chemicals, with each score being a product of scores representing population, toxic potency and exposure potential. To work properly, the scores for these three factors would have to be approximately proportional to the estimated values of the factors. For population and potency the answer would be relatively easy, but the exposure score would probably need to be constructed from scores representing various factors related to exposure, such as mass of chemical deposited, containment efficacy, mobility, and persistence.

Exactly how this is done is not as important as that the rules for scoring factors are consistent with the rules for combining scores, and that both are reasonably consistent with how the factor enters the risk equation in a risk assessment.

In contrast, the rules for combining scores in the current HRS do not always reflect relative risk. Scores often rise as the logarithm of the factor value being scored. For example, each order-of-magnitude increase in potency may receive an additional point, and each factor of two or two-and-a-half increase in population at risk may receive an additional point. Using logarithmic scores is an appropriate way to account for a wide variation in magnitude of the possible values for factor scores; furthermore, logarithmic scores can be added to simulate multiplication of the underlying factors. For example, when the HRS assesses a site with carcinogens, the population at risk can be estimated by multiplying the size of the population at risk by the risk per individual which can be estimated as the product of the exposure of each individual by the potency of the carcinogen. The combining rule should add the logarithmic scores corresponding to the three factors. In the case cited, however, the logarithms are to different bases; potency is scored by a logarithm to the base 10, but population is scored approximately to the base 2.3. Because $(2.3)^3$ is approximately equal to 10, it takes 3 population points to be equivalent to 1 potency point, and the potency scores must be multiplied by 3 (or population scores divided by 3) before they are added. In this case, the HRS "weighting factor" of 3 is exactly what is called for by the existing science. It is a natural outcome of the simplification process and not a subjective "weight". In the HRS, the weights do not always conform to the science, and the combining rules are not always consistent with the scoring rules or with one another.

The use of a scoring system to place sites on the NPL is certainly appropriate and, as scoring systems for priority setting go, the HRS is already better than most. Almost all of the factors scored are plausibly related to risk and generally one point means the same in different parts of each scale, usually a change of an order-of-magnitude or a constant factor.

However, the current HRS is not always internally consistent in the number of points which relate to a change in risk. For example:

1) A single point does not have the same mathematical relationship to the final score in one part of the algorithm as a single point has in another. This variation in scoring implies different assumptions about how the factors relate to risk.

2) Subjective weighting factors are included. For example, the route scores are combined by a route mean square rule so that when one route dominates, it alone is enough to place a site above the cut-off. (However, at many sites, the risk through one route will usually dominate the other two. Whether or not such weights should be used is debatable. However, if weighting is used, it should be explicit.)

3) The rules for combining some scores in the current HRS do not relate properly to the observed behavior of those factors. For example, consider the way in which the total waste characteristics score is derived from its components. It is the sum of the component scores for quantity and toxicity/persistence (toxicity and reactivity for the air route).

> Technically speaking, a site with much harmless material could be eligible for the NPL if it receives the maximum scores for observed release/route characteristics containment, quantity, and targets.

This is an extreme case. However, the combination of summation and multiplication in the algorithm has problems beyond this rather artificial example. A useful interpretation of the current HRS would be that since both toxicity/persistence and quantity scores appear to be logarithmic, summing them would be correct for assessing the total waste characteristic score on the logarithmic scale. However, the same interpretation does not hold for other parts of the algorithm. For example, the component scores for observed release/route characteristics-containment, total waste quantity characteristics, and targets -- are multiplied. If the same logarithmic interpretation is to be applied to these components, then all those multiplications should be changed to summations. Otherwise, the summation in the waste characteristics score should be changed to multiplication. The underlying question is whether the entire score should be interpreted on the logarithmic scale.

For another important component, observed release/route characteristics containment, the scale used for scoring appears to be the probability of release instead of its logarithm.

There are two important concepts here. First, the way the scores are combined should reflect the way those components relate to one another in the real world. Secondly, the final HRS score should be on some kind of easily understood scale (arithmetic, probability, logarithmic, etc.) so that the relative risks presented by various sites can be easily understood. "Normalizing" scores among routes only makes sense if one believes that 100 points implies the same risk through each route. On the other hand, there is no easily implemented way of interpreting any of the scores and the equality assumption is not disprovable.

Aggregation of Pathway Scores

A variety of methods can be used to aggregate pathway-specific scores. If sufficient structural information on the pathways scores is available, such information should be used in choosing the aggregation method. For example, if the pathway scores are constructed on the logarithmic scale, the exponential averaging method should be used. If the pathway scores are constructed on the arithmetic scale, the linear averaging method should be used.

The quadratic averaging method used in the current HRS is not only arbitrary but, from a scientific viewpoint, arguably incorrect. OPPE reported that its unpublished Site Ranking Panel study compared three different aggregation rules: linear averaging, quadratic averaging, and cubic averaging. The results (within the limitations of the study) indicated that the panel's final ranking was closest to cubic averaging.

In the absence of sufficient structural information on the pathway scores, the choice of the aggregation method reflects the subjective judgment on the relative importance of single- and multiple-pathway sites. An important class of aggregation rules is the k-th power averaging method in which the score for each pathway is raised to the power k, calculating the average across pathways, and then taking the k-th root. The linear averaging method is $k = 1$ and $k=2$ is the quadratic averaging method. Large values of k give less prominence to the pathways with lower scores, making it easier for single-pathway sites to get on the NPL. Small values of k give more prominence to pathways with lower scores, making it easier for multi-pathway sites to get on the NPL.

There are two other important aggregation rules. The worst case method takes the worst of the pathway scores. The exponential averaging method exponentiates the pathway scores, takes the average across the pathways, then takes the log. The two methods should yield very similar results, giving little prominence to pathways with lower scores and making it easier for single-pathway sites to get on the NPL. Both methods can be viewed as generalizations of the k-th power averaging method with k approaching infinity.

How can the HRS make better use of temporal analysis?

Analyzing how long it takes to analyze a site through the various steps between identification and remediation yields information which has implications for parts of the HRS—especially the toxicity/persistence score and in considering population dynamics. If, for example (and this currently seems to be the rule rather than the exception), the site remains unremediated for a long period of time, then chronic effects become more important than acute and the HRS should address them. (See Appendix 2 for a discussion of acute and chronic effects at unremediated sites.)

By analyzing information about the source and migration (and also anything else that would remove wastes from the site, such as decomposition), it is possible to estimate the length of time a site may present a problem. Such an estimate has implications for remediation.

Similarly demographic and other relevant changes which may be predicted over time could alter the nature and degree of risk posed by a site. Because such factors alter risk, the revised HRS should not ignore them.

What can be done about the quality of the data used in the HRS?

A major effort should be made to improve the overall quality of analytical data collected at sites. Standardized collection and laboratory methods currently exist for only a small fraction of substances potentially present. Expanded chemical characterization of all media, coupled with a strong laboratory certification program, will improve not only the HRS but all aspects of the Superfund process.

Similarly, acceptable data collection procedures should be established (or expanded upon) for non-analytical data (such as population estimates, volume of wastes, etc.) so that the best quality data will be preferred. Mechanisms which could be used to encourage the collection and use of quality data include: a tiered data quality approach such as the one OERR presented to the Large Volume Waste Work Group, data collection "trees", and the weighting of final HRS scores to account for the quality of data used in generating it.

What can be done when there isn't "enough data" for the HRS?

It is necessary to have a method of default (also termed missing value replacement values) when data are limited or nonexistent for chemicals. Lacking complete information on chemical inventory and concentration at a site may well be the rule rather than the exception. Therefore, a standardized approach to the circumstance will reduce the inconsistencies that are inevitable if such decisions are left to field staff or if only the "better" data are somehow selected and used.

Several approaches can be used for assigning a value to a scoring component when data are not available. One way is to assign a zero. This would be a mistake. However, because it underestimates risk. (However, on a logarithmic scale, assigning a zero may, in fact, overestimate risk. If the risk should be very small, the logarithmic score should be appropriately negative--even minus infinity, if the risk is zero arithmetically.)

From a scientific perspective, a better way is to use auxiliary information on the site to help impute the missing value.

One concern with this approach is whether the fact that the data are missing might be an indication that the site might be different from otherwise comparable sites.

The definition of comparable sites is crucial and may depend on the scoring component. For quantity and concentration, gross categories of sites could be used (as a minimum). Stratification by region is also possible, leading to a definition of comparable sites such as those of the same category in the same geographic region. When possible, comparable sites should be defined to allow the use of the greatest amount of data.

There are two general statistical approaches for defining comparability in this situation. First, one can develop a metric to measure how comparable two sites are in terms of the auxilliary characteristics, then choose a prespecified number of sites closest to the specific site in terms of the given metric. Second, one can use an empirical model to describe how the scoring component depends on the auxilliary characteristics, then use the prediction from the model to impute the missing value for the specific site.

Incorporation of a large number of auxilliary characteristics is not a trivial task. It might not be worth the effort to go beyond the use of broad site categories and regions. The decision depends on whether other characteristics could be powerful predictors of the scoring component being considered.

In some situations, limited data about the site will exist. Averaging those data is an easy measure of central tendency likely to represent the site better than any of the individual numbers. For example, if a few concentration measurements are available, even if variable and of uncertain quality, their average can be taken to show relative quantity in the absence of better information. Alternatively, some sense of proportion can be gleaned from the types of wastes known to have been deposited at a site. For example, relatively low concentrations (compared with average waste materials) of all hazardous chemicals are expected in fly ash, but metals and products of incomplete combustion (dioxins and furans) would be more likely present than volatile organics.

Another approach may be used when some data is available. It is known to statisticians as the shrinkage formula and to the actuarial literature as the credibility method. This approach uses data both from the site and from sites thought to be comparable. The Subcommittee is not in a position to evaluate how difficult the field staff would find implementation of this approach.

What should be done when data are available that exceed what is needed for the HRS ?

One approach is the assignment of discretionary points (which the Subcommittee has sometimes called the "Bump Factor"). The Subcommittee discussed several scenarios where such discretionary points could be usefully assigned such as in the case of a site where:

1. Many chemicals were identified (only some of which were data available for evaluating toxicity but where the presence of other implied additional risk).

2. The presence of the toxic materials in the surrounding target population had been demonstrated.

3. Acute exposures to air emissions were possible from catastrophic release or other changes in site conditions.

4. One or more contaminants were known to be extremely toxic to indigenous natural populations.

5. Human effects had been confirmed and those effects could be reasonably linked to exposure to particular chemicals from the site.

6. Nuisance levels of chemicals in the air around the site were identified of and their presence confirmed (best analytically, but possibly by smell).

This approach could also be used to take better account of non-human receptors. The idea is to assign extra points which are proportional to the extra risk the situation presents.

Caveat

If the algorithm is changed, then the 28.5 cut-off score should be re-evaluated. The threshold S_m, which determines whether a site is eligible for the NPL, needs to be adjusted when either the algorithm is changed or when more routes are incorporated because the same score will not necessarily have the same meaning. For routes already used in the HRS, OERR should investigate from existing data what alternative threshold should be used in order to yield a pre-specified proportion of sites on the NPL, if the algorithm is changed.

A5-12

APPENDIX 6

RECOMMENDATIONS TO EVALUATE AND IMPROVE THE HRS

BY THE

HAZARD RANKING SYSTEM REVIEW SUBCOMMITTEE

OF THE

SCIENCE ADVISORY BOARD

RECOMMENDATIONS TO EVALUATE AND IMPROVE THE HRS

How Good Is the HRS?

The HRS is appropriate for the purpose for which it is intended. As a scoring systems for priority setting, it is better than most. The factors scored (with possibly one or two exceptions) are related to risk, and higher scores for them reflect higher risks. Thus, the current HRS is plausible. The recommendations concerning the algorithm discussed in Appendix 5 should greatly improve it.

HOW CAN EPA LEARN FROM EXPERIENCE TO BETTER PREPARE FOR THE NEXT REVISIONS?

OPPE Study. In considering the HRS as a predictor for a comprehensive risk assessment, it is natural to clarify how well it performed in the past. The unpublished OPPE Site Ranking Panel study (18, 23) did not address this question but focused entirely on subjective evaluation. For parts of the HRS (route characteristics and containment), additional data are available. It should be possible to conduct an empirical evaluation using RI/FS and/or other data to evaluate the HRS score both for sites on the NPL and for those that did not score high enough for the NPL.

Empirical Evaluation. The HRS performance should be judged by an empirical retrospective evaluation of how successfully the HRS predicts risk or by how successfully its components predict phenomena (such as release) which contribute to risk. This evaluation should be based on an in-depth technical review. Whatever the definition of risk, the HRS should be judged on how well it approximates that definition, not on how well it matches some subjective notion of the relative importance of the sites in a test set.

With respect to empirical evaluations, the route characteristics and containment scores are estimates for the probablity of release when actual release is not detected. Two distinct probabilities need to be considered: (a) the probability that current releases are not detected, and (b) the probability that such releases will occur in the future. For the latter, the time horizon also needs to be considered. For the sites with sufficient RI/FS and/or data from studies by the states or other parties, it should be possible to search for the best way to predict release from the components of route characteristics and containment scores.

Comparison of Data and Scores for the Same Site. Given the screening nature of the HRS, as a screening tool, it does not appear cost-effective to attempt to establish confidence intervals rigorously. However, some sefinition of uncertainty would be useful for interpreting the scores. If re-evaluations are available for some available for some sites, it would be useful to compare the data obtained from the separate inspections of the site. State data, frequently used in HRS scoring, might also be used for this purpose.

What Kinds of Data Should the Agency Collect and What Kinds of Studies Should it Conduct to Support Future HRS Revisions?

There are two goals for such studies. First, the Agency should improve the algorithm to be defended as risk-related and, second, the studies should develop at least a crude way to estimate the quantity of specific chemicals present. The planning of any evaluative studies should be carefully peer-reviewed before being implemented.

As mentioned in the Other Comments portion of Appendix 3, EPA also should develop studies to review large volume waste sites ranked under the model and to examine basic parameters of the model. A study in the first category suggested by Mr. R. Walline of EPA Region VIII could address the actual reasons why release occurred at problem mining sites (reasons reportedly are different than those initially assumed) and a study in the second category might address the characteristic(s) of mining waste that control release (mobility) to ground water.

APPENDIX 7

REQUESTS
FROM THE
OFFICE OF EMERGENCY AND REMEDIAL RESPONSE (SUPERFUND)
TO THE
SCIENCE ADVISORY BOARD

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 9 1986

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

MEMORANDUM

SUBJECT: Science Advisory Board Review of Hazard Ranking System

FROM: Henry L. Longest II, Director
Office of Emergency and Remedial Response

TO: Dr. Terry Yosie, Director
Science Advisory Board

The Office of Emergency and Remedial Response (OERR) is conducting a review and possible revision of the Hazard Ranking System (HRS). OERR is requesting that the Science Advisory Board review several issues in conjunction with this effort.

BACKGROUND

The HRS is the principal mechanism used by EPA to determine whether to place sites on the National Priorities List (NPL), promulgated under Section 105 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). The HRS was promulgated on July 16, 1982 (47 FR 31219), as Appendix A of the National Contingency Plan (NCP). The current HRS evaluates the relative potential of uncontrolled hazardous substances to cause human health or safety problems, or ecological or environmental damage, by taking into account "pathways" to human or environmental exposure in terms of numerical scores. Those sites that score 28.50 or greater on the HRS, and which are otherwise eligible, have been placed on the NPL. A site must be on the NPL for it to be eligible for remedial action financed by the CERCLA trust fund.

On October 17, 1986, CERCLA was amended. The Superfund Amendments and Reauthorization Act of 1986 (SARA) requires EPA to promulgate changes to the HRS 18 months after enactment. The amendments require EPA to modify the HRS so that, "to the maximum extent feasible, it accurately assesses the relative degree of risk to human health and the environment posed by sites and facilities subject to review." Specifically, the amendments require:

- An assessment of the human health risks associated with contamination or potential contamination of surface waters, either directly or as a result of the run-off of any hazardous substance, pollutant or contaminant. This assessment should take into account the use of these waters for recreation and the potential migration of any hazardous substance, pollutant or contaminant through surface water to downstream sources of drinking water

- An evaluation of the damage to natural resources which may affect the human food chain and which is associated with any release or threatened release

- An assessment of the contamination or potential contamination of the ambient air which is associated with a release or threatened release

Section 125 of SARA requires EPA in its revision of the HRS, to specifically assess those wastes described in section 3001(b)(3)(A)(1) of the Solid Waste Disposal Act. These wastes include fly ash waste, bottom ash waste, slag waste and flue gas emission control waste generated primarily from the combustion of coal or other fossil fuels. The amendments require EPA to consider:

(1) The quantity, toxicity, and concentrations of hazardous constituents which are present in such waste and a comparison with other wastes;

(2) The extent of, and potential for, release of such hazardous constituents into the environment; and

(3) The degree of risk to human health and the environment posed by such constituents.

Additionally, section 118 of the SARA states that EPA shall give a high priority to facilities where the release of hazardous substances or pollutants or contaminants has resulted in the closing of drinking water wells, or has contaminated a principal drinking water supply.

In the amendments to CERCLA, Congress has stated its intention that the HRS remain a screening tool to enable EPA to list sites on the NPL as expeditiously as possible, using data from the Preliminary Assessment (PA) and Site Inspection (SI). The legislative history of SARA makes clear that Congress did not intend that the revised HRS become a mechanism for making detailed risk assessments; rather, it was intended to be consistent with the limited purpose of the NPL--screening sites that might, after further study, warrant Fund-financed remedial action.

In order to improve the accuracy of the HRS, the Agency is considering expanding the data collection performed before a site is proposed for the NPL, to provide data to implement a revised HRS. To maximize the use of these limited resources, EPA must target its data collection activities to those specific areas that would most increase the accuracy of the HRS.

ISSUES FOR REVIEW

Based on the public comments received during the rulemakings for the initial NCP (47 FR 31180, July 16, 1982), the original NPL (48 FR 40658, September 8, 1983), and the subsequent NPL updates, as well as the intent of Congress and program experience, OERR has begun a review and revision of the HRS. In conjunction with this review, OERR has analyzed the HRS and developed technical issue papers on selected aspects of the ranking scheme.

Specific issues we would like the Science Advisory Board to review at this time include:

- A review of the scientific factors in the existing HRS to recommend how these might be modified to enhance its effectiveness.
- An evaluation of the way the HRS evaluates waste characteristics, particularly as it relates to mining waste sites, a critique of several reports on mining waste issues, and a review of a technical paper exploring the potential use of concentration data in the HRS.
- An examination of the toxicity ranking scheme employed in the existing HRS and OERR's suggestions for modifying this scheme.
- An analysis of the distance used to determine the target population potentially affected by the release of hazardous substances to the air.

OERR will outline each specific issue more fully to better focus the Science Advisory Board's review in a memo accompanying each report.

Review of The Scientific Factors in the HRS

We would like the Science Advisory Board to review the current HRS and those specific factors that make up each scoring pathway. As part of this review, we are requesting that the Science Advisory Board rank the existing HRS factors in order of their importance in accurately assessing risk from a release of hazardous substances. We would also like the Science Advisory Board to evaluate the appropriateness of the weighting factors currently used in the HRS and recommend how these might be modified to enhance the effectiveness of the HRS. The intent of this is to help OERR focus our HRS revisions effort, as well as our expanded data collection activities.

In the existing HRS, the score for a facility is based on the potential for harm to humans or the environment from migration of a hazardous substance from a facility by routes involving ground water, surface water or air. It is a composite of separate scores for each of the three routes. The score for each route is obtained by considering a set of factors that characterize the potential of the facility to cause harm. Each factor is assigned a numerical value (on a scale of 0 to 3, 5 or 8) according to prescribed guidelines. This value is then multiplied by a weighting factor yielding the factor score.

Waste Characteristics/Mining Waste Issues

In scoring a site using the current HRS, EPA considers the quantity of hazardous waste deposited, rather than the quantity of hazardous constituents within these wastes. EPA also does not consider the quantity of hazardous constituents released into the ground water, surface water, or air, but only whether that release is significantly above background. When EPA developed the HRS, the Agency believed that determining the quantity of hazardous constituents would require a significant amount of sampling and analysis that would result in substantial delays in the ranking of sites.

In its various rulemakings on the NPL, EPA has received public comments on this aspect of the HRS and how it is used to evaluate mining waste sites. The commenters have stated that the HRS is biased against high-volume, low-toxicity wastes, such as mining wastes, because it does not take into account quantity, toxicity and concentration of the hazardous constituents, and that EPA is unable to provide evidence that the HRS is a rational basis by which to rank mining sites for inclusion on the NPL.

OERR would like the Science Advisory Board to evaluate the HRS in light of these criticisms, and to review both a technical paper on the HRS developed by TRC, Inc. for the mining industry, and a critique of the TRC mining report conducted by OERR's contractors. As part of this review, we would like the Science Advisory Board to examine the validity of the mining industry's concerns and to recommend areas for revision of the HRS, if warranted, to address these concerns, keeping in mind the use of the HRS as a screening tool for further studies.

In addition, we would like the Science Advisory Board to review a technical paper developed by OERR that explores the use of concentration data in evaluating hazardous waste sites. This review should focus on the feasibility of including waste concentrations in the HRS, the data requirements and resource implications of implementing such a change, as well as the reliability of sampling data to accurately determine the quantity of hazardous constituents contained in wastes.

Air Target Distance Limit

Currently, the air pathway of the HRS relies on analytical data that shows levels of a contaminant at or in the vicinity of a facility that significantly exceed the background levels. The air pathway provides a score based on the toxicity of the substance released via the air route, and the population within a four-mile radius of the site. This population is used as an indicator of the population which may be harmed should a hazardous substance be released to the air.

OERR has analyzed the distance used to determine the target population potentially affected by a release of hazardous substances to the air and prepared a technical report detailing its findings. The report presents conclusions on the general level of cancer risk arising from uncontrolled waste sites and examines the implications of the analysis for the distance factor of the air pathway. The study used an EPA model called Human Exposure Model (HEM) to make these estimates.

We would like the Science Advisory Board to evaluate the target distance limit used in the air pathway of the existing HRS and review the technical paper developed on this subject. As part of this review, we would like an assessment of the general methodology used in the technical paper and the implications of these findings on the air pathway factor of a revised HRS. In addition, we would welcome any suggestions concerning general approaches for revising the air targets distance limit.

Toxicity

Many public comments have been received by EPA on the method used in the HRS to rank the toxicity of hazardous substances. The current method is based on a rating scheme developed by N. Irving Sax (1975, 1979, 1984) and rates the toxicity of hazardous substances on a scale of 0 to 3. The rating is primarily based on acute toxicity. Several technical issues have been raised by commenters that suggest the possible need for modification of the HRS is in order to improve its ability to discriminate among sites whose wastes have different toxicity characteristics.

As a result of these comments and the intent of Congress to make the HRS as accurate as possible, OERR has evaluated the method currently used in the HRS for estimating the relative toxicity of substances at hazardous waste sites and the methods employed by other ranking systems to evaluate toxicity. Based on the review, OERR has suggested improvements to the HRS toxicity factor that incorporate measures of acute, sub-chronic and chronic toxicity.

We would like the Science Advisory Board to evaluate the toxicity ranking scheme employed in the existing HRS, to review OERR's technical paper on this subject, and to suggest improvements to the HRS that would more accurately assess the toxicity of a hazardous substance.

SCHEDULE

The specific technical reports for Science Advisory Board review will be made available to you 30 days in advance of the Science Advisory Board meeting. We would be more than happy to meet with the Science Advisory Board to brief them on the existing HRS, if appropriate.

Thank you for your help in this project. If you have any questions concerning OERR's requests, please contact Jane Metcalfe at 382-7393. We look forward to working with you on the HRS revisions effort.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 25 1987

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

MEMORANDUM

SUBJECT: Science Advisory Review of the HRS

FROM: Henry L. Longest II, Director
Office of Emergency and Remedial Response

TO: Dr. Terry Yosie, Director
Science Advisory Board

In December 1986, I requested the Science Advisory Board (SAB)'s assistance in reviewing several issues related to OERR's efforts to review and revise the Hazard Ranking System (HRS) as directed by Congress in the Superfund Amendments and Reauthorization Act of 1986 (SARA). In response to this request, an Ad Hoc HRS Subcommittee was formed by the SAB. This Subcommittee met for the first time on May 19 & 20, 1987. By this memorandum I wish to express OERR's appreciation to the Subcommittee and SAB staff for their responsiveness to our request and the expressed willingness to work within the narrow time constraints for the revisions imposed by SARA. I would also like to take this opportunity to confirm several key points which should facilitate the Subcommittee review.

Purpose of the HRS

During the initial meeting on May 19 & 20, many members of the Subcommittee posed questions concerning the purpose of the HRS. As pointed out, the purpose of the HRS is a major determinate of the structure and function of a model. Such a model is required to prioritize actual or potential hazards to public health and the environment posed by hazardous waste sites. OERR believes that the purpose of the HRS is primarily a screening tool used to determine which sites will be candidates for Fund-financed remedial response. To the degree possible, the model also needs to provide a stratification of sites based upon the relative risks posed to human health and the environment. OERR does not believe that the HRS is intended to assess absolute risk, since it is to be applied early in the remedial site evaluation process. OERR intends to revise the HRS to the maximum extent feasible, to estimate more accurately the risks associated with a site. In conducting these revisions, however, OERR will balance the benefits of increased accuracy against the associated costs, avoiding revisions that would require far more extensive data and, in so doing, impede the ability of the HRS to function expeditiously.

OERR's Objective on Seeking SAB Review

Congress, through SARA, requested that in our review of the HRS, we assess several specific areas. In reviewing these areas, OERR is particularly concerned that our decisions concerning the approaches used in revisions be supported by sound technical and scientific analyses. Peer review of the technical or scientific issues under consideration will provide essential support for any proposed revisions.

Specific Issues For SAB Review

OERR requests that the Subcommittee examine three specific HRS revision issues: 1) the method(s) used to assess toxicity, 2) the air target distance limit and 3) whether large volume wastes should be considered differently from other wastes. These issues are described briefly in the December 9, 1986 memorandum and will be developed more fully in issue papers to be presented to the Subcommittee according to the schedule agreed to at the May 19 & 20, 1987 Subcomittee meeting. As I understand, the following schedule has been agreed to by all parties:

1. Toxicology Panel -- June 29 & 30
2. Meeting 2 of Subcommittee -- July 16 & 17
3. Air Panel -- July 27 & 28 (issue paper to be mailed July 1)
4. Large Volume Waste Panel -- Aug. 19 & 20 (issue paper available July 17)
5. Final Subcommittee Meeting -- Sept. 14 & 15 (tentative)

In my December 9, 1986 memorandum, I requested SAB review of the fourth issue involving the review of scientific factors in the HRS. The scope of that review was to prioritize the various ranking factors in terms of their importance to assessing risk and evaluate the appropriateness of the weightings assigned to those factors.

As explained by Craig Wolfe during the May 19 & 20, 1987 SAB meeting, OPPE has assembled a group of Agency officials to discuss the importance and weighting of various risk related factors and rank order 20 hazardous waste sites. I believe that the work of this expert panel will be most satisfactory in answering the questions related to the factors and weightings in the current HRS. Consequently, I believe it would be duplicative to continue my request to the SAB for such a review and therefore, I withdraw this part of my request for review to the SAB.

OERR believes that the issues presented to the Subcommittee meet the criteria identified in the Administrator's guidance concerning use of the SAB, and can be addressed as discrete issues. While we intend to provide updates to the Subcommittee on overall progress with respect to revisions of the entire model, we do not believe that review of the overall model is either feasible or appropriate for the Subcommittee due to the need for policy as well as scientific considerations.

OERR looks forward to continuing the open and focused review effort which was initiated at our first meeting. If you have any questions please contact Ms. Penny Hansen, Deputy Director of the Hazardous Site Evaluation Division at 475-8600.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUL 28 1987

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

MEMORANDUM

SUBJECT: Science Advisory Board (SAB) Review of Mining Waste/Concentration Issues

FROM: Stephen A. Lingle, Director S. Lingle
Hazardous Site Evaluation Division

TO: Terry Yosie, Director
Science Advisory Board

Thank you for the opportunity to introduce the mining waste and concentration issues to the full subcommittee. Mr. Richard Conway, chairman of the High Volume Waste Panel expressed his desire to have OERR further define the issues for SAB consideration. The purpose of this memorandum is to provide this clarification.

As presented in the July 16, 1987 subcommittee meeting, the two issues related to mining waste sites are:

1) Applicability of the HRS in scoring mining waste sites; and

2) Feasibility of using waste concentration data in a revised HRS.

The first issue has been raised by the mining industry during public comments on various NPL rulemakings. The commenters have stated that the HRS is biased against high-volume, low concentration wastes, because it does not take into account quantity, toxicity, and concentration of the hazardous constituents. The commentators also stated that EPA is unable to provide evidence that the HRS is a rational basis by which to rank mining sites for inclusion on the NPL.

OERR would like the SAB to evaluate the HRS in light of these comments, and to review three technical papers on the HRS developed by TRC, Inc. for the mining industry, and two reports prepared by OERR's contractors. As part of this review, we would like the SAB to examine the validity of the mining industry's concerns with respect to high volume waste sites such as mining sites. Although the papers discussed in the first issue pertained to mining waste, OERR believes that the issue is equally relevant to sites containing other high volume wastes such as fly ash.

The second issue is related to the first as it addresses the feasibility of using the concentration of the hazardous constituents of wastes. In response to public comments that concentration data are not used in the current HRS to determine the quantity of hazardous waste, and the requirements of SARA Section 125(a), EPA developed an option that specifies three-tiered methodology that allows the use of waste concentration data. This methodology is described in the concentration issue paper presented to the SAB.

In revising the HRS, Section 125(a) of SARA requires EPA to address quantity, toxicity and concentration of hazardous constituents for RCRA Section 3001(b)(3)(A)(i) special study wastes (fly ash, bottom ash wastes, and flue gas emission control waste generated primarily from the combustion of coal or other fossil fuels). Although, SARA Section 105(g) does not require revisions to the HRS, it does require that EPA consider the same factors (quantity, toxicity, and concentration) in the decision to propose new mining waste sites to the NPL using the current HRS until the HRS is revised. EPA believes that the methodology described in the third option of the concentration issue paper could be employed to satisfy Section 125(a) and would also address concerns about scoring other high volume waste sites such as mining waste sites as well. Consequently, we believe that the subcommittee findings will be equally applicable to both mining and fly ash sites.

I hope that this discussion provides the desired clarification of this issue. In addition, we are in the process of gathering available information on costs of waste sampling and analysis at large volume waste sites. This information will be provided to the SAB members as soon as possible.

OERR appreciates the time and effort the subcommittee members have expended and we look forward to our next meeting in Denver. If you have any additional questions, please contact Agnes Ortiz of my staff, at (202) 475-9700.

Attachments

cc: Kathleen W. Conway
SAB Subcommittee Members

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APPENDIX 8

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